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ABSTRACT

This guide outlines the initial work and includes recommendations for schools and districts on how to implement an integrated science program. Chapters include: (1) "What Is Integrated Science and What Does It Look Like at the High School Level?"; (2) "Coherence in High School Science" (F. James Rutherford); (3) "Thinking about Change: What Will It Take to Implement an Integrated Science Program?"; (4) "Supporting Change through Professional Development" (Rodger W. Bybee and Susan Loucks-Horsley); (5) "How Do We Assess Learning in Integrated Science?" (Kathy Comfort); (6) "Thinking about Implementation: The Road Ahead"; (7) "How Have Others Done It?"; (8) "California Scenario" (Marilyn Perron); (9) "Utah Scenario" (Sue Faibisch); and (10) "Florida Scenario" (Ginger Davis and Raul Montes). Appendices include: (1) "Using the Concerns-Based Adoption Model When Implementing Integrated Science Programs"; (2) "A Short Cut for Model IV"; (3) "A Needs Assessment for Integrated Science"; (4) "Next Step Questions to Consider Before Making a Decision"; (5) "The Integrated Science Program at Your School: Guidelines for Writers"; (6) "Frequently Asked Questions about Integrated Science at the High School Level"; (7) "List of Curriculum Materials for Integrated Science and Survey Results." (Contains 50 references.) (YDS)

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MAKING SENSE OF INTEGRATED SCIENCE

A Guide for High Schools

BSCS

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About This Guide

This guide is a result of a BSCS design study, which was funded by the National Science Foundation. We collaborated with staff from the American Chemical Society, the American Institute of Physics, and the American Geological Institute as well as with science educators and teachers of integrated science from across the country to study the status and structure of current programs in integrated science and the potential need for others. We intend this guide to provide teachers, schools, and districts a framework within which to think about the process of implementing an integrated science program and to prepare for the changes that will be a necessary part of that process. Because any significant change can be challenging, it is important that all stakeholders think carefully and clearly about the process before setting out on the journey. This guide will help structure that process.

We begin in Chapter 1 with background information about integrated science and provide a series of snapshots of what integrated science

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looks like and might look like at the high school level. This chapter also develops the rationale for offering integrated science as a coherent and viable alternative course of study for high school science. Chapter 2 examines factors that contribute to the capacity for change as well as specific types of change that are necessary when implementing an integrated science program. In Chapter 3, the guide then goes on to examine many of the practical aspects of implementing a new course of study. In this chapter, we provide guidelines that will help teachers and schools examine closely where they are and where they want to be. A framework for change from the district perspective along with a detailed road map will help schools track the priorities of each major component of the process at each juncture.

Chapter 4 presents an opportunity for the reader to examine three scenarios. These scenarios trace the development of three different programs of integrated science that exist in three different parts of the country and in three different types of districts. These scenarios depict a range of successes and challenges and present detailed descriptions of the impetus for change, the decision-making process, the challenges that the schools faced, how each challenge was addressed, and where each school is headed. These scenarios will allow teachers and administrators to peek through the window of another school and learn some practical, as well as philosophical, lessons from them. At various points in the report, we present reflective essays that address in greater depth ideas and issues related in integrated science programs. The guide ends with a set of appendices, which provide practical tools for schools and districts.

This guide outlines the initial work that any school or district would need to undertake if it were to implement an integrated science program. This guide is not a curriculum framework that is ready to be put in place, and it does not make specific recommendations about decisions of a particular school district. This guide, however, may help schools and districts in their information gathering and decision-making process and then provide practical guidance to schools as they take the first steps in the process of implementing integrated science programs.

As the integrated science field continues to evolve, feedback from teachers and administrators is important to us. Please take a few moments and fill out our online Evaluation Survey at www.bscs.org.

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We want to thank everyone who contributed time, ideas, and high-quality work to this project. A study of this type is collaborative in nature and requires a high level of commitment; we are grateful for the contributions of the advisory board members, reviewers, guest writers, production experts, technology experts, our designer, and our editor.

THE BIOLOGICAL SCIENCES CURRICULUM STUDY

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Introduction

Defining the Problem: An Impetus for Change

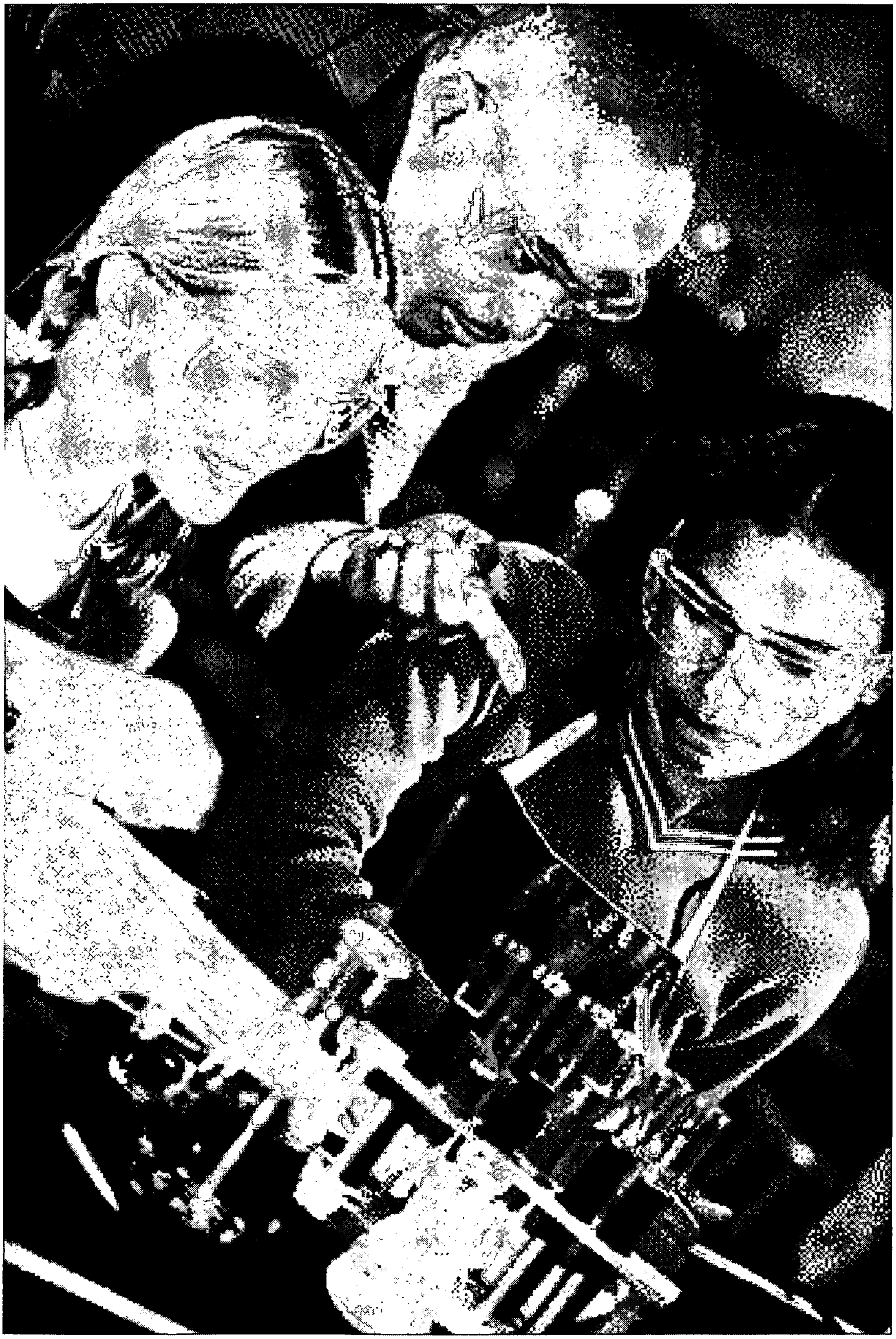
Following the call for reform in science education in the 1980s, which began with *A Nation at Risk* (National Commission on Excellence in Education, 1983), school districts in the country started taking a hard look at what had been passing for science education in their schools, and they began making commitments to do things differently. In general, since that time, the country has seen some success in improving the science programs of elementary schools and middle schools. Reform-based curricula with a conceptual approach to science, based on current research in teaching and learning, have been developed and implemented. The high school community, however, generally has been slower to shift and hesitant toward change, notwithstanding some highly successful examples of reform here and there.

Now, more than a decade later, we are faced with another compelling call to action. Scientists and science educators across the country have developed *Benchmarks for Science Literacy* (American Association for the Advancement of Science [AAAS], 1993) and the *National Science Education Standards* (National Research Council [NRC], 1996), both of which clearly outline new, coherent recommendations for what students should know and be able to do in science. Many of our country's current science programs lack the rigor and depth necessary to improve students' literacy in science and help them meet these standards across the disciplines.

The results of the Third International Mathematics and Science Study (TIMSS) indicate that high school students in the United States significantly lag behind their counterparts in many other countries with respect to their understanding of basic concepts in the sciences. This research provides further evidence that our school science programs fall short (International Association for the Evaluation of Educational Achievement [IAEEA], 1998).

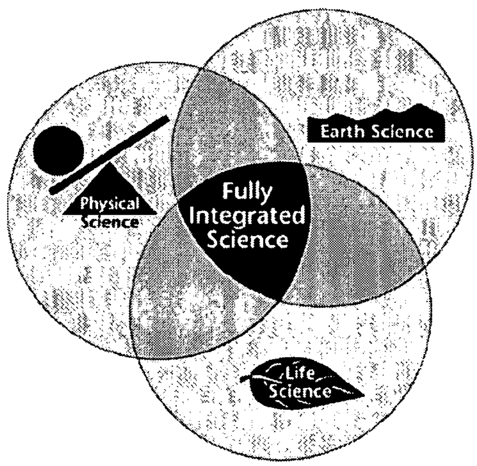
Fortunately, the impetus for change in high school science programs appears to be mounting. This impetus has a *sui generis* nature from district to district, but one of the common goals is exploring a new direction. Teachers across the country are calling for a course of study in the sciences at the high school level that presents a coherent alternative to the traditional track of biology, chemistry, and physics.

In this new terrain, school communities will seek their own path. The process of uncovering a path, finding answers, and implementing change, however, is not simple or easy. BSCS has been studying the landscape of high school science for two years, and we offer this guide as an initial tool for schools that are considering a journey into the world of integrated science. We think that a conceptually coherent science program that integrates content knowledge across discipline boundaries might provide substantive opportunities for learning for a broad range of students.



CHAPTER ONE

What Is Integrated Science and What Does It Look Like at the High School Level?



INTEGRATED SCIENCE: WHAT IS IT?

Is there consensus about the definition of "integrated science"? If one looks up the word *integrated* in the dictionary, one finds that the word means "combining parts into a whole." In science then, what are the parts that we might bring together? It is quite natural to identify the parts as the separate disciplines of science, such as earth science, life science, and physical science. It is quite natural to consider as well the processes of science, such as inquiry, and the contexts of science, such as science and society and science in history. So without too much trouble, we have an initial idea of what parts we might bring together and what integrated science might be. How do teachers and science educators use the term? Do we all mean the same thing? And what does the landscape of integrated science at the high school level look like? How was this landscape formed? In this chapter, we will develop answers to these questions.

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Addressing a Confluence of Conditions

Often when educators suggest a new approach to teaching or a new research-based idea about learning, the initial response is, "Yes, that makes sense," or "Oh, that would be a good idea," or "I know that would work better for my students." But often the approach is eventually dismissed because "It takes too long," "It is too much work," or "What I am doing works okay." A single, new idea often is insufficient to catalyze change.

The impetus for change is more substantial, however, when there exists a confluence of conditions. Such is the case now in science education. The *National Science Education Standards* (NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993) outline clearly what all students should know and be able to do in science. We also know that, based on the science classes that students currently take in high school, most students do not meet these standards. When you add to this mix the recent results of the Third International Mathematics and Science Study (IAEEA, 1998), which indicate that high school students in the United States are significantly behind their counterparts in other nations, the shortcomings become even more apparent.

In response to this confluence of conditions, most states are taking action. States are increasing the number of science credits that are required for graduation from high school. The intention of this action is to increase all students' exposure to science and, as a consequence, it is hoped, their understanding of it. In an effort to monitor their students' progress in learning, states also are implementing exams in basic literacy throughout the K–12 years and as high school exit requirements; many of those exams include the sciences (Council of Chief State School Officers, [CCSSO], 1998).

The impetus for change is more substantial when there exists a confluence of conditions. Such is the case now in science education.

State departments of education and school districts also are developing their own sets of standards and curriculum frameworks, most of which are modeled after *Standards* and *Benchmarks*. In 1998, forty-one states had content standards in the sciences that were ready for implementation (CCSSO, 1998). As districts attempt to help teachers implement these standards, however, they are finding a paucity of instructional materials that meet their needs. Many districts,

schools, and teachers have resorted to putting together their own materials as well as using materials from a number of different sources. The result often has been programs that lack coherence and that have not been field tested or reviewed (BSCS survey and personal communication, 1997–2000).

Integrated science, it seems, may be one viable alternative for meeting the science literacy needs of a diversity of students.

The students who take earth science in middle school and then go on to take biology, chemistry, and physics in high school are the most likely to have the opportunity to meet all of the standards in science and to do well on the exit exams. We know, however, that this is a small subset of our students. What about the majority of students who are not personally or academically inclined to complete this sequence? Integrated science, it seems, may be one viable alternative for meeting the science literacy needs of a diversity of students.

History

In response to this emerging set of conditions, BSCS began to think about developing a high school curriculum in integrated science. Teachers and administrators had been telling us for years that existing materials were inadequate for the large number of students who eschewed the traditional earth science-biology-chemistry-physics sequence. It is clear, however, that the landscape of high school science programs includes some rough terrain. Consequently, before we jumped into a comprehensive curriculum project, we undertook a careful study of the landscape.

We knew from several reports that states were increasing science requirements for graduation. Currently, forty-two states require two or more years of science for graduation. Fifteen of those states require three years in science, and one state requires four years (see Figure 1.1). Seven states have increased these requirements since 1996. Other states are considering increasing their current requirements (CCSSO, 1998). Despite this trend, and somewhat counterintuitively, the number of students enrolled in the traditional science courses does not seem to be increasing. We know that many ninth- and tenth-grade students take biology, but in spite of the modest increase in the past few years, the numbers still drop off significantly in chemistry and drop off even more significantly in physics.

As we began looking for an explanation for this situation, we found a tremendous number of different science courses that schools offer to students. Currently, students seeking to meet their graduation requirements through an alternative to the traditional sequence are faced with myriad options from aerospace studies to animal behavior (see Figure 1.2). Although these options increase the students' exposure to a range of intriguing specialty topics in science, it is unlikely that they contribute to improving students' understanding of fundamental concepts in the core sciences. Unfortunately, as well, many of those courses do not align with state or national curriculum frameworks. This patchwork nature of high school science results in curricula that are "a mile wide and an inch deep" (Schmidt, McKnight, & Raizen, 1997) and contributes little to a student's overall science literacy. This patchwork approach also results in courses of study that lack coherence. The need for coherence is the topic of the first invited essay in this guide, "Coherence in High School Science," by F. James Rutherford.

State Science Credit Requirements for High School Graduation, 1998

States that require three or more years of science	Alabama Arkansas District of Columbia DoDEA Florida Georgia Hawaii Kentucky	Louisiana Maryland Mississippi North Carolina Tennessee Virginia West Virginia Wyoming
States that require two years of science	Alaska Arizona California Connecticut Delaware Idaho Indiana Kansas Maine Missouri Montana Nevada New Hampshire	New Jersey New Mexico New York North Dakota Oklahoma Oregon Rhode Island South Carolina South Dakota Texas Utah Washington Wisconsin
States that require one year of science	Illinois Ohio	
States in which requirements are determined by district or are under revision	Colorado Iowa Massachusetts Michigan Minnesota Nebraska Pennsylvania Vermont	

Source: CCSSO, 1998.

Figure 1.1 Currently, forty-two states require two or more years of science for graduation.

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•Aerospace Studies	•Genetics
•Anatomy and Physiology	•Geology
•Animal Behavior	•Human Physiology
•AP Environmental Science	•Integrated Physics/Chemistry
•Applied Biology/Chemistry	•Integrated Sciences
•Applied Earth Science	•Life Science
•Applied Physical Science	•Limnology
•Applied Physics	•Marine Biology
•Aquatic Science	•Meteorology
•Astronomy	•Microbiology
•Biological Agriscience	•Molecular Biology
•Botany	•Nuclear Radiation
•Chemistry/Physics Foundations	•Oceanography
•Consumer Chemistry	•Organic Chemistry
•Earth Science	•Physical Science
•Earth/Space Science	•Principles of Technology
•Ecology	•Science and Technology
•Environmental Systems	•Seminar in Science
•FAST (Foundational Approaches to Science Teaching)	•Space Science
•Fresh-Water Ecology	•Unified Science
•General Sciences	•Weather
	•Zoology

Figure 1.2 In high schools across the country, myriad options are available in school science programs in addition to biology, chemistry, and physics.

Together, the growing need for an alternative in school science programs and the general lack of coherence in the current offerings in nontraditional science selections convinced BSCS of the need for a sound integrated science curriculum that would contribute significantly to the science literacy of a broad range of students. Integrated science represents a viable alternative to the traditional sequence; it is not necessarily better than or more effective than the traditional sequence.

Beginning to Define Integrated Science

As we began to explore existing programs in integrated science and to discuss what a new curriculum in integrated science might look like, we discovered a range of ideas about exactly what integrated science is and what such a curriculum should look like. Within the mix of integrated science, we find the notions of coordinated science, unified science, alternated science, and interdisciplinary studies

as well. For some, the term integrated science encompasses all of the terms; for others, each term means something specific and excludes each of the others.

The distinction that is most often articulated is the one between integrated science and coordinated science. Ideally, in integrated science, students explore cross-disciplinary concepts in each lesson. For example, in a lesson about weather patterns, students might uncover concepts in earth science (rotation of the earth and orientation of the earth in space), concepts in physical science (convection and flow of energy), and concepts in life science (the effect of weather on living organisms). On the other hand, in true coordinated science, students explore discipline-specific concepts in a layered fashion where the students' experience is coordinated in a logical way but there are not explicit connections between the disciplines. For example, students might explore a concept in physical science for several weeks before moving on to a lesson in the life sciences. Next, they would complete a lesson in earth science before returning to explore another set of concepts in the physical sciences. In reality, what we find is that, in many instances, a program referred to as integrated science is actually more coordinated in nature, and what some refer to as coordinated, indeed, is often integrated to some extent.

Within the mix of integrated science, we find the notions of coordinated science, unified science, alternated science, and interdisciplinary studies.

Many teachers and science educators feel that it is not realistic to expect that each lesson in an integrated science program would integrate all of the sciences. They argue that often in a lesson only two of the sciences are integrated and sometimes only one predominates. This feature, they argue, is important because in some cases students must have a clear understanding of a basic concept in one of the disciplines before they can explore the concept further in an integrated context. Take the example of weather patterns again. It is likely that students would need to complete an activity that focuses only on the physics of energy before they explore how energy contributes to various weather patterns. These teachers and science educators argue that trying to present concepts from each of the sciences in each lesson becomes contrived.

In this guide, we will use the term integrated science in its broadest interpretation. Basically, if a course presents students with opportuni-

ties to uncover concepts from each of the sciences during the year in a substantial way and to make coherent connections between them, we will consider the course to include integrated science. Because of the reality of the landscape, we need to recognize a continuum of integrated science courses, both with respect to degree of integration and with respect to the amount of time a teacher devotes to it.

Many preliminary discussions about defining integrated science begin with the issue of content. What content is it that we should integrate?

Some individuals use the term *interdisciplinary* as a synonym for integrated. It seems more common, however, to use the term interdisciplinary for course work that brings together content from more widely separated areas, such as science and social studies or science and language arts or social studies and language arts. In this guide, we will reserve the term interdisciplinary for cases such as these.

In the remainder of this chapter, we will continue to develop a comprehensive and flexible definition that should accommodate the needs of most teachers and districts.

Many preliminary discussions about defining integrated science begin with the issue of content. What content is it that we should integrate? What content should we teach to students who do not pursue the traditional earth science-biology-chemistry-physics (EBCP) sequence? It is clear that the answer to that question is not qualitatively different from the answer to the related question, What content should we teach to students in the EBCP sequence? In fact, if we believe that *Standards* and *Benchmarks* really do define scientific literacy, then the answer to both questions is the same. *Standards* and *Benchmarks* should define the content of any science program, regardless of whether it is traditional or integrated in structure.

In the case of integrated science, then, we agree that *Standards* and *Benchmarks* for grades nine through twelve represent the core scientific content that *all* students should learn. Of course, that content includes not only understandings and abilities related to the various science disciplines and inquiry but also related concepts in the history and nature of science, the personal and social perspectives of science, and science and technology.

From both conceptual and political standpoints, defining content in this way offers an obvious advantage: It does not assume or require that ability be considered when determining whether integrated science is appropriate for a particular audience. The content itself can be presented in more or less challenging ways regardless of whether it is organized in the familiar sequence or as an integrated course of study. The concept of energy flow through systems, for example, is independent of the structure of the curriculum and of the students in the course. Curricula can present energy flow to students in very concrete ways—by following what happens to packaging materials as they move from the manufacturing plant to the consumer to the landfill or recycling center—or in more abstract ways—by tracing how energy is captured from the sun and stored in the structure of organic molecules. Thus, we can develop a curriculum in integrated science for honors students and another for average students, just as we have done for decades in biology, chemistry, and physics. Indeed, Brevard County, Florida, the subject of one of the scenarios presented in Chapter 4, has done exactly that.

To successfully address the needs of a diversity of students with respect to interest level, motivation, and ability, there must be flexibility and excellence throughout the overlapping layers of the broader system, which includes policies and philosophies at the district level, the structure and scope of the science program, and the fine art of teaching and assessing student learning. Each of these areas has its own set of standards, and each represents often-overlooked, yet critical, elements of a sound school science program.

Educators tell us that integrated science is a valuable and viable alternative because it engages a greater diversity of students, it reflects the unifying concepts and principles of science, it reflects the reality of the natural world, and it may better prepare students to think comprehensively about an increasingly complex world.

Our analysis of *Standards* suggests that a minimum of two years is necessary to provide learning experiences that introduce the *core* science content. That estimate assumes a focus on inquiry, life, earth and space, and physical sciences and minimizes substantive exposure to the science and technology, science in personal and social perspectives, and history and nature of science standards.

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Realistically, a one-year program in integrated science is inadequate if science literacy is the goal. Of course, one year of biology in a state that requires only one year of science for graduation would fall hopelessly short of literacy as well. Two years of integrated science represents a minimum, and three or four years offers the greatest opportunity for depth of coverage in each discipline. Fortunately, states are increasing their science requirements, as we mentioned earlier.

WHY BOTHER?

Given all that we have said up to this point, why do we think that integrated science represents a viable alternative to the traditional sequence and addresses many of the converging needs in school districts across the country? From a BSCS survey that has been in circulation during the past two years, we have heard from teachers and administrators in forty-six states. These educators tell us that integrated science is a valuable and viable alternative because it engages a greater diversity of students, it reflects the unifying concepts and principles of science, it reflects the reality of the natural world, and it may better prepare students to think comprehensively about an increasingly complex world (BSCS survey and personal communication, 1997–2000).

Because integrated science reflects the unifying concepts and principles of science as well as the reality of the natural world, teachers tell us that, in their experience, this makes science seem relevant and connected to the lives of a diversity of students. Problem- and project-based approaches, for example, that blur the boundaries of the sciences and allow students to investigate a range of concepts across the

Some teachers have told us that integrated science is the only way that the majority of students will meet these standards.

disciplines present students with a "need to know." This need to know engages the students when it is connected to a problem that the students find meaningful, such as Why are the fish in our pond dying? or How can I determine what material is best for the siding on a greenhouse? Broad themes and unifying principles also provide a rich context and a creative learning environment. Integrated science programs with lessons such as these tend to engage the students and keep them motivated to learn. When students are studying the

Figure 1.3 When students are presented with a "need to know," many are motivated to learn.

physics, chemistry, life science, and earth science of a forest fire, for example, there is a meaningful connection; many students will have heard about specific fires; others may have been evacuated from an area because of the threat of a spreading fire; a few may have experienced firsthand the effects of a forest fire. Forest fires represent a reality to which many students will have a personal connection.

Because all students are not equally engaged by science for science' sake, integrated science, which seems relevant and connected to real experiences in their lives, may be a more effective way to teach a diversity of students. Regardless of whether students are in a traditional sequence or an integrated sequence, as they are presented with in-depth opportunities to explore cross-discipline concepts and solve cross-discipline problems, it is likely that they will be better prepared as science-literate citizens to interact and participate more fully in a complex world.

It is clear that states and districts are developing their own set of standards and curriculum frameworks, many of which are modeled after *Standards* and *Benchmarks*. In 1998, forty-one states had con-

tent standards in the sciences that were ready for implementation (CCSSO, 1998). As districts attempt to help teachers implement these standards, however, they are finding a paucity of instructional materials that meet their needs and help students meet their state standards in two or three years. Some teachers have told us that integrated science is the only way that the majority of students will meet these standards. Consequently, states such as West Virginia are mandating that integrated science be taught at grades nine and ten (BSCS survey and personal communication, 1997–2000).

States and districts also are implementing statewide assessments throughout high school and as high school exit exams. Twenty-two states currently have exit exams that test students in a set of core content; eight more are in the process of developing such assessments. In all such states, these exams include the basic skills of language and math; in an increasing number of states, these exams include the sciences (CCSSO, 1998). Again, many teachers suggest that integrated science courses are the only viable alternative for helping students attain a degree of science literacy across the disciplines and be successful on the increasing number of statewide assessments in science.

Because integrated science courses may offer students these important opportunities, it seems likely that school districts should at least investigate the possibility of offering integrated science as an alternative course of study.

Completing the Definition: Models, Vehicles, and Grain Size of Integration

Experiences in integrated science can take on many shapes by making use of a range of different vehicles of integration and by being developed for a range of grain sizes. As a result of this mix, we have developed six major models of instruction. It is possible to view these models along a continuum, and each model may have several variations. For example, in one model, students might experience a single activity that integrates two or three of the science disciplines and takes up only one or two class periods. In another model, students might experience a multiyear program that integrates all of the major disciplines of science in an ongoing experience.

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SIX MODELS

I. The first model is a traditional sequence of earth science, biology, chemistry, and physics, with no conceptual connections among the sciences. This model includes no integrated content.

II. A. One variation of the second model is the traditional, discipline-based sequence with some conceptual connections *within* each discipline. This model includes no integrated content.

B. Another variation of the second model is the traditional, discipline-based sequence with some conceptual connections *between* the disciplines.

In biology, when students investigate photosynthesis, they also study the chemistry involved as plants convert light energy to chemical energy, which is then available to the plant for growth and reproduction.

III. The third model is a coordinated program with each discipline being taught each year (perhaps grades nine through eleven). This is basically the *Scope, Sequence, and Coordination* model (NSTA, 1996). Several variations are possible here, some with equal emphasis given to each science and some with certain sciences predominating at specific points.

Scope, Sequence, and Coordination *provides microunits that align with specific content categories, which some teachers then map to their state standards or national standards. These microunits (for example, "Neurons and the Nervous System," "Animal Behavior," "Density of Rocks," and "Physical Properties of Matter") provide specific lessons with specific foci and can be taught in any order.*

IV. The fourth model is a disciplined-based or coordinated program for most of each year of a three- or four-year program, with one integrated science unit at some point during the year, perhaps an initial or a final unit.

Following three units of biology, students might investigate natural disasters that occur on earth and during their investigation learn about important, related concepts in the physical and earth sciences.

V. The fifth is a model that includes a full year of integrated science at ninth grade followed by the traditional, discipline-based sequence for grades ten through twelve. Another version of this model might be the traditional sequence for grades nine through eleven and a capstone course at twelfth grade.

In Utah, many districts require an earth systems course for ninth graders. Within this context, students explore concepts in the earth sciences (how the earth and our solar system were formed and continue to evolve), life sciences (how life forms on earth adapt to their environment), and physical sciences (how convection and the Coriolis effect account for weather patterns on earth). (See the Utah Scenario in Chapter 4.)

VI. The sixth model includes two, three, or four years of a full integrated science program.

Brevard County, Florida, developed its three-year integrated science course for high school around eight strands that were articulated by the Florida Science Curriculum Framework: The Nature of Matter; Energy; Force and Motion; Processes That Shape the Earth; Earth in Space; Processes of Life; How Living Things Interact with Their Environment; and the Nature of Science. (See the Florida Scenario and the California Scenario in Chapter 4.)

Each of the six models represents a different pathway through science teaching and learning. A school district would need to discuss all aspects of each model thoroughly and then determine which best matches its goals for students with respect to what it wants its students to know and be able to do in science. For example, a school district might ask itself the following questions: What represents excellence for us? What will offer us the most coherence in our science program? What are the advantages and disadvantages of each model with respect to the students and learning, the teachers and teaching, the science disciplines, and assessment? and What are the implications of our decision?

What Do We Mean by a Vehicle for Integration?

Curriculum developers use a variety of approaches, perspectives, or themes to increase students' interest in science, to carry a message that has social or historical importance, or to provide an intellectual

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and scholarly coherence to a body of work. Developers refer to these approaches, perspectives, or themes collectively as *vehicles. Active Physics,* for example, uses as a vehicle a series of relevant challenges that require students to draw conclusions from experiments in sports, medicine, transportation, or other integrating topics. BSCS has used integrating themes as a vehicle for more than forty years in its high school biology texts *An Ecological Approach* (Green Version), *A Molecular Approach* (Blue Version), and more recently, *A Human Approach* (Human Version). BSCS also has developed comprehensive, thematic-based integrated science texts at the elementary and middle school level.

Broadly speaking, vehicles for integration may include a variety of themes—content themes such as energy or systems, process themes such as inquiry or the nature of science, and issues such as science-technology-society (STS) topics. Vehicles also include project- and problem-based approaches and research initiatives at the local, national, or global level, as shown in Figure 1.4.

POSSIBLE VEHICLES FOR INTEGRATING THE SCIENCES

Vehicle	Example
Broad-based themes	patterns, systems, evolution
Science-technology-society issues	pollution, transportation, energy use
Process themes	inquiry, nature of science
Topics	wildfires, earthquakes, properties of materials
Projects	building an effective greenhouse
Research initiatives	local issues such as "Why are the fish dying in our lake?"

Figure 1.4 A variety of vehicles for integrating the content are possible.

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What Do We Mean by Grain Size?

When considering the possible ways in which to construct an integrated science curriculum, one can imagine a range of time frames. Edmund Burke's *Connections* series on television thoroughly presents integrated science and technology in self-contained, one-hour segments, which might be the equivalent of a single classroom lesson. This is an example of a small grain size. At the other end of the continuum, one can imagine integrating a student's entire high school science experience during a three-year sequence using a spiraling thematic approach to science content and process. This would be an example of a large grain size. In between, teachers can integrate science content across a week, a multiweek unit, or a full quarter or semester, with the remaining time devoted to more traditionally organized content. With respect to grain size, Models IIB-VI described earlier are generally organized from a small grain size to a large grain size.

In general, when planning for an integrated science experience of a particular grain size, either small or large, school districts and teachers might want to consider a range of vehicles. To demonstrate the flexibility of a particular vehicle of integration with respect to grain size, it might be useful to consider one vehicle, such as issues in science-technology-society and examine the possibilities in a range of grain sizes (see Figure 1.5).

For an example of Model IIB, a teacher in an earth science class might end a unit on the behavior of matter within the earth with a lesson on recycling. In this lesson, the teacher might use this STS issue to bring together concepts from earth science (cycles of matter) and life science (the effects of certain materials on living organisms) and then examine how we can recycle materials safely. In Model IV, another earth science teacher might design an entire unit on recycling that gives the students the opportunity to explore related concepts in the earth and life sciences as well as to investigate concepts from the physical sciences such as tracing the flow of energy and the chemical breakdown of matter.

In another school, a teacher teaching a year-long integrated science course (Model VI) might design a series of units using several different STS issues such as global warming, natural disasters, sustainability, and world population. In another district, teachers might use similar STS issues to develop a two- or three-year program in

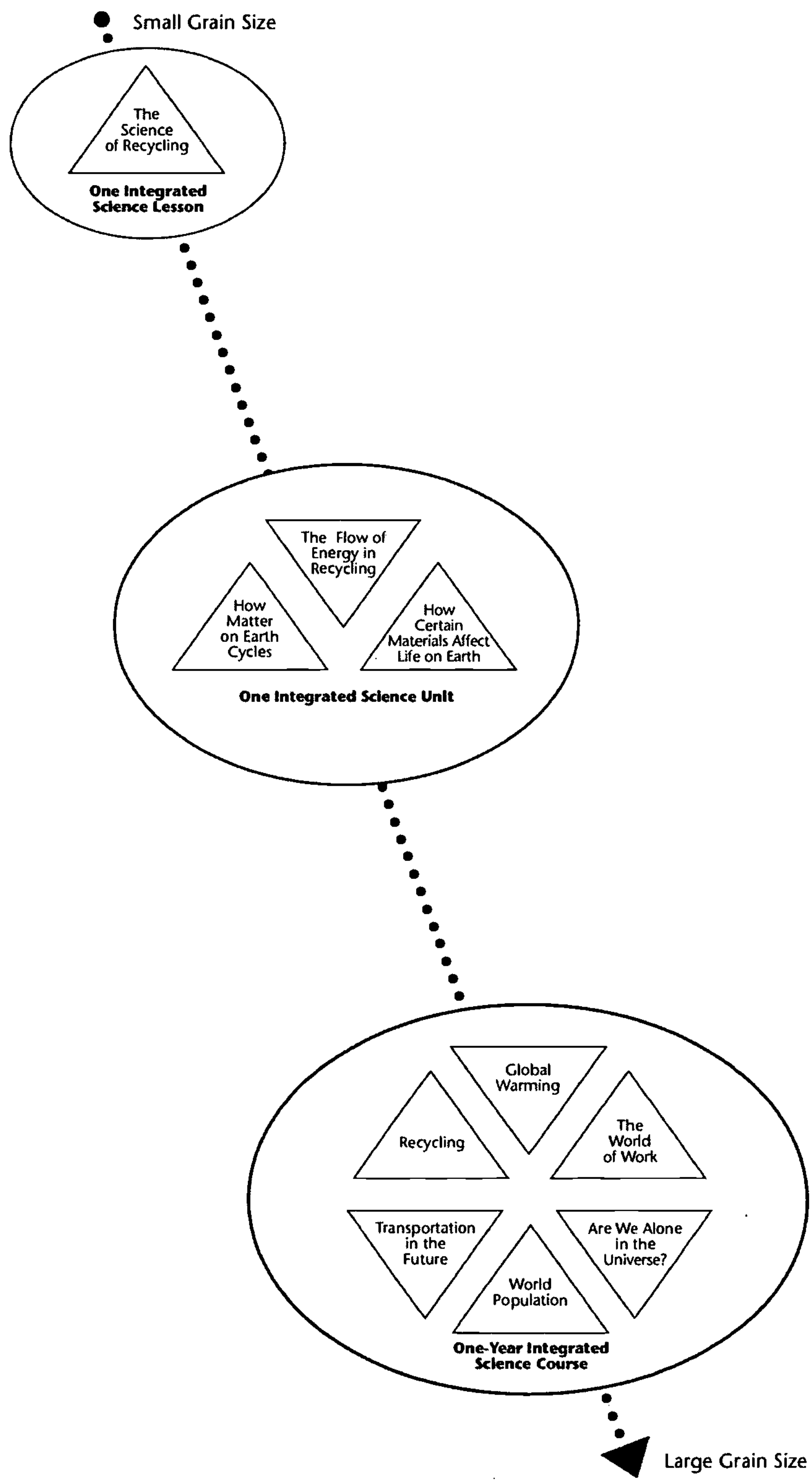

Figure 1.5 A particular vehicle for integration may be flexible in ad- ing to a range of grain sizes.

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integrated science. Some science educators feel that certain vehicles such as STS may be better suited for a particular grain size. For example, a vehicle such as inquiry may have a greater carrying capacity for integrating the science content than others. This notion of carrying capacity would be important to consider, especially for a multiyear program.

Scientific ideas presented without conceptual coherence have little chance of enduring in the minds of many students.

It is also important for school districts to realize that the choice of a particular vehicle of integration and grain size will have curriculum-design implications. Suppose, for example, that a district decides to design a two-year integrated curriculum using themes such as systems and change as the vehicle. In order to build such a curriculum, the district must engage in extensive planning, collaboration, and a study of middle school-high school curriculum articulation. For example, a district team would need to plan how students' experience with systems and change in year two will build on their experiences from year one and how year one will build on what the students studied in middle school. Obviously, this would require greater collaboration between teachers and administrators than would a single unit that used a problem-based learning vehicle.

Another fundamental consideration when developing any integrated science curriculum is whether the content is conceptually coherent. If big ideas do not connect logically and obviously, then student learning is uncertain and tentative. Lacking power, scientific ideas presented without conceptual coherence have little chance of enduring in the minds of many students. This aspect of the integrated science landscape is explored in the following essay.

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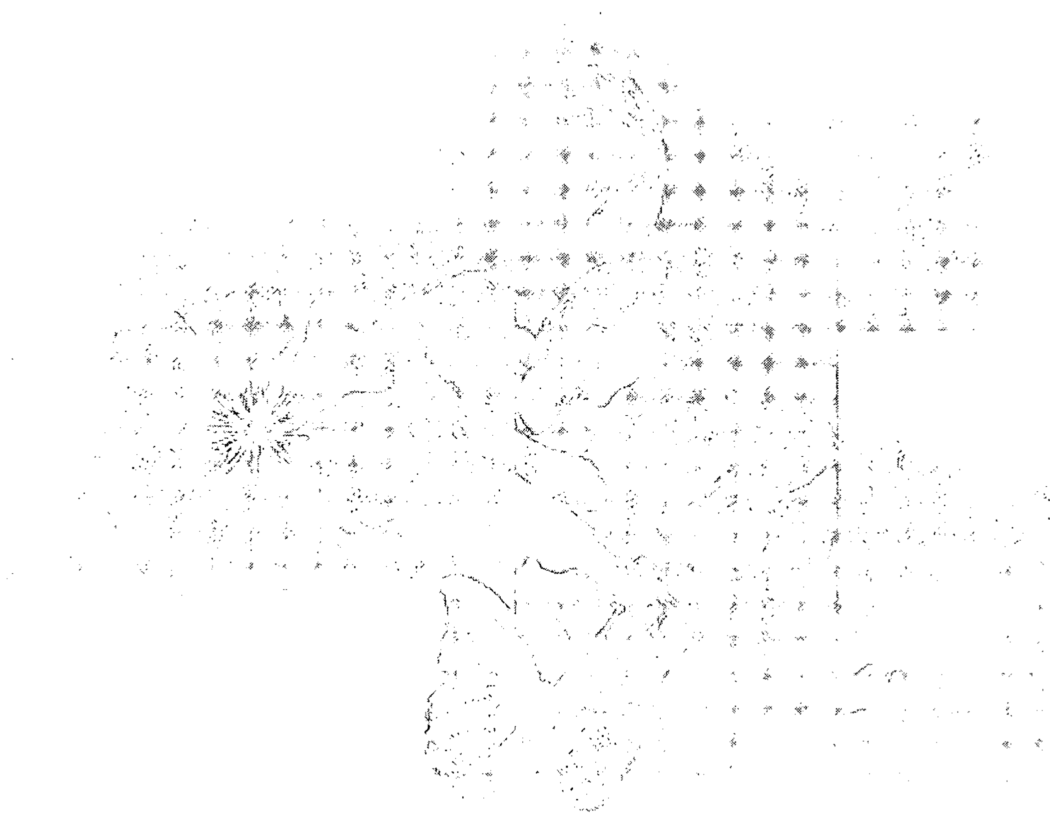

Coherence in High School Science

by F. James Rutherford
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Coherence, it appears, is held in high esteem. Its presence in most objects, activities, processes, organizations, and systems is applauded, its absence deplored. In general, the notion of coherence itself is simple enough. It has to do with relationships. Things are coherent if their constituent parts connect to one another logically, historically, geographically, physically, mathematically, or in some other way to form a unified whole. Coherence calls for the whole of something to make good sense in the light of its parts, and the parts in the light of the whole.

Fair enough. But difficulties show up when one tries to apply the general idea of coherence to particular entities or domains. Picasso's *Guernica*, Shakespeare's *Hamlet*, the United States Congress, highway systems, newspapers, farms, clocks, space missions, department stores—in each, purposes, constraints, understandings, traditions, and values shape how the idea of coherence is put to work. In a word, coherence is extremely contextual. Here, the context is high school science, more specifically the conceptual coherence of high school science courses that feature integrated content.

Coherence, Teachers, and Developers

One might, of course, wonder about the importance of coherence in high school science courses, for in truth there is little empirical evidence to back up the conviction that it much matters. But if coherence is taken to mean simply that the parts of a course come together to form a conceptual

whole—in contrast to a collection of indistinctly related topics, concepts, and facts—then few of us would argue against it, and most would take it to be a necessary attribute of good high school science courses. The value of coherence in high school science is not at issue, it would seem, at least not in principle. But its relative absence is.

Teachers and publishers may both say that coherence is important, yet the most widely used high school science textbooks are not notable for their coherence. It is, of course, not uncommon in educational affairs for a substantial gap to exist between proclaimed principles and actual practices, but why would it be so with regard to coherence? It would, after all, not seem to be all that elusive a target. Perhaps we are confronted here with the classic chicken-egg situation: Teachers do not select coherent textbooks because publishers do not make them available; publishers do not create coherent textbooks because teachers do not demand them.

Assuming that commercial publishers will ultimately produce the kinds of materials that will sell well—demand preceding supply—an essential step in narrowing the coherence gap is to foster teacher demand. It is not enough that adoption committees admire coherence; they must be able to recognize its presence and to compare competing textbooks with regard to it. And then they must give it a high priority in making a final decision, picking the textbook, other things being reasonably equal, that is the most coherent (even if none are admirably so).

But there is a hitch. It is that little guidance is available for science teachers on what specifically to look for with regard to coherence, or for publishers on what properties to build into their textbooks in order to make them coherent. There are, however, some examples to draw ideas from, including most of the high school science courses created in the sputnik era of school reform, and a few more recent ones. The suggestions put forward below are influenced by *Project Physics* (Holton, Rutherford, and Watson, 1970), which from the outset had conceptual coherence as a major aim, and also by the current work of Project 2061 on how to analyze curriculum materials (soon to be published in *Resources for Science Literacy: Curriculum Materials Evaluation*, American Association for the Advancement of Science [AAAS], in press).

Coherence, Courses, and Textbooks

If coherence in high school science courses is a desirable property, then one can reasonably argue that it should be present at every level of content organization: lessons, units, courses, sequences of courses, and entire curric-

ula. Thus, the topics and activities making up a science lesson or chapter ought to connect with one another to tell a (very limited) story, with, as it were, a discernable beginning, middle, and end. Similarly, the lessons or chapters making up a science unit should connect one another in interesting ways to tell a complete (but still limited) story, and units should connect with one another in interesting ways to tell a more comprehensive story. Notice that two conditions must prevail at each level of organization: All of the parts forming a unit or course must be coherent, and all of those parts must join together to form a conceptual whole.

This line of reasoning suggests that the course is the most effective starting place for estimating the coherence of high school science programs or for developing new ones. First one asks, what story is the science course claiming to tell (or, if being developed, intends to tell) about the natural world, or some important aspect of it, about science itself, and about the connection between them? Then, do the units composing the course actually tell that story, or, in the case of courses in development, what collection of coherent units should be created and connected to tell that story effectively? One cannot expect to create a coherent course simply by selecting units (even coherent ones) from a large set of units and introducing them in any order.

When going up the scale to more encompassing levels of content organization—course sequences and entire curricula—achieving coherence becomes increasingly problematic. The idea is sound enough, but practical difficulties abound. Even so, proponents of course sequences should be expected to articulate what unifies the courses and to identify the main conceptual and developmental links among the courses. Designing an entire core curriculum is vastly more complicated still. For an extended discussion of what is involved, see *Designs for Science Literacy*, a new publication of Project 2061 (AAAS, 1999).

Assuming that, in the context of high school science, the course is the starting place of choice for evaluation or development purposes, the question of what constitutes a given course arises. For most purposes, including developing coherent courses and evaluating the degree of coherence of existing courses, the textbook (which here is always taken to include its accompanying teacher guide or handbook) is the most accurate and complete proxy. While it is true that some high school teachers place little or no reliance on textbooks, that surely is not the usual case. For all intents and purposes, and for the foreseeable future, the textbook is the course—or at least its most observable and consistent manifestation.

Unfortunately, that is not terribly reassuring, given that today's popular high school science textbooks are noted more for their gargantuan size than for their intellectual coherence (among their other prevalent but needless faults). All too often, high school science textbooks tell a muddled story, if any story at all, its chapters, however well written individually, and its topics, however numerous, not adding up to a unified, compelling whole. The reasons for this are well understood, but not easily corrected, as Harriet Tyson (1988) has so clearly described in *A Conspiracy of Good Intentions: America's Textbook Fiasco*. Perhaps the greatest enemy of coherence in high school science textbooks is inclusiveness—the fear of leaving anything out. The texts are mindlessly overstuffed with topics, facts, principles, illustrations, quizzes, and terminology, smothering any possible thematic unity. In this, they are unlike good science trade books, such as those identified for teachers in *Resources for Science Literacy: Professional Development* (AAAS, 1997). In any case, a coherent high school science textbook will be modest in size, limited in content, and tell a compelling story about the scientific view of the natural world.

Coherence in Perspective

Nothing said so far should be taken to suggest that coherence is the be all and end all of good high school science. Coherence is but one property of good course content and does not address the equally important pedagogical attributes of a good course. In developing a method for evaluating instructional materials and creating a database of reviewed materials, Project 2061 took both content and instruction into account, as did the Office of Educational Research and Improvement of the U.S. Office of Education in identifying promising and exemplary materials for science and mathematics courses. The two approaches, though somewhat different in organization and language, are pretty much in accord.

A modern course should be designed to target a set of explicit learning goals decided on in advance.

As proposed in *Resources for Science Literacy: Curriculum Materials Evaluation*, the content of science courses should have four properties. First, it should be **significant**. It is not reasonable to expect students to learn all of the facts, concepts, and principles in the world of science or to become knowledgeable about all of the topics to which science relates. Choices have to be made, and those choices should favor the content that will best serve students for a lifetime in the real world of ideas and action. And of course, the content should be **accurate**. Errors of fact and wrong or misleading pre-

sentations of laws, principles, and concepts have no place in science courses—though leavened, of course, by the realization that the expression of content needs to be age appropriate. Third, content should be **aligned** with desired or declared learning goals. Developers often claim this for their products these days, but actually honor it more in rhetoric than in practice. And then there is **coherence**.

Manifestations of Conceptual Coherence

Making the claim of coherence is as easy as it is common. But what kind of detectable evidence would the skeptic—or alert textbook selection committee—look for to test the claim? Or, to move to the supply side of the street, what would developers build into their courses if they wanted to validate their claims? Consider the following:

A modern course should be designed to target a set of explicit learning goals decided on in advance. In order for the course to be coherent, so should its goals. Fortunately, in science, resources exist making it easy for both teachers and developers to identify a body of coherent learning goals. These are found in the content standards portion of the *National Science Education Standards* (National Research Council [NRC], 1996) and in *Benchmarks for Science Literacy* (AAAS, 1993). The latter was derived directly from *Science for All Americans* (AAAS, 1989), and hence it is possible to see how the individual benchmarks join to form a larger and more coherent whole.

A coherent course tells a story—or, more likely, many interconnected stories within a grand story—about some important aspects of the natural world and science, or it should. This is to say that a high school science textbook should be of a piece conceptually, and so should the chapters or other major parts making up the whole. Furthermore, just as in the plot of a good novel, the science story should be progressive, steadily building toward an increasingly rich landscape of understanding. This position—that for courses to be coherent, the ideas and skills in them must be interconnected and progressive—is emphasized in *A Guide for Designing Coherent Curriculum Programs in Mathematics and Science*, a recent report of the National Research Council, and in various of the Third International Mathematics and Science Study (TIMSS) reports (IAEEA, 1998).

Another property to look for (or to build in) is the presence or absence of themes that run through the entire course, illustrating what is common among what otherwise might appear to be quite separate chapters and units. The themes can be ideas about nature (conservation, say, or evolution); the nature of science (that science is a blend of logic and imagination, perhaps,

or that scientific knowledge is durable though subject to change); the history of science (dependence of scientific advances by one person or group on the work of others in other places and other times, the inevitability of unexpected applications); the impact of science (human health, the environment, warfare); the interactions with other domains (mathematics, technology, history, literature, art); scientific ways of thinking and doing (quantitative reasoning, hypothesis testing); and any number of other possibilities.

As one examines the smaller components of a high school science textbook (chapters, individual topics, ideas, and so on), the connections among them take on importance. For instance, every major concept that appears needs to be linked logically to the evidence supporting it and conceptually to related concepts. When principles are adduced, they should be illustrated with a variety of applications in separate locations in the book, not simply once when introduced. Not everything in a coherent course needs to be related to everything else in it, but there should be few isolated pieces of content to be found. The growth-of-understanding maps in the *Atlas of Science Literacy* (AAAS, in press) offers examples of some interesting conceptual connections across grade spans.

Coherence and Integrated Curricula

Integrated courses are not automatically interesting or relevant or understandable, and certainly not intrinsically coherent. They have to be made so, just as do discipline-centered courses. In fact, when it comes to coherence, the latter have a leg up. As put in *Designs for Science Literacy* (AAAS, 1999):

> Although many kinds of coherence are possible, traditionally coherence is assumed to reside naturally in the college disciplines. Since each of the disciplines at any time more or less defines a body of knowledge and its organization, language, and practices, the disciplines themselves seem to provide a ready-made framework for creating a coherent curriculum. The prominence of biology, chemistry, and physics in the science curriculum reflects this premise, as do arithmetic, algebra, and geometry in the mathematics curriculum.

In principle, if not always in fact, a discipline-based high school science course gives primacy to the knowledge, methods, structure, language, and applications of a discipline, or significant parts of a discipline, and reflects the coherence of that discipline. By way of contrast, the content of integrated courses is selected and limited and perhaps justified by themes,

social or environmental issues, phenomena, problem solving, or other nondisciplinary organizers, or by some combination of disciplines, and can be quite idiosyncratic. In essence, integrated courses have no ready-made framework for creating coherence, and so it must deliberately be built into them.

Discipline-based high school science courses may have a conceptual head start with regard to coherence, but an examination of textbooks quickly makes it clear that few of them are in fact impressively coherent. They contain the words but not the music. Perhaps designers of discipline-based courses assume—quite mistakenly—that the intrinsic coherence of the discipline will automatically appear along with the borrowed content, and consequently invest little thought in creating the interconnections, themes, and story lines that are essential for coherence. But as just noted, designers of integrated courses can be under no such illusion.

And that is good news. It alerts developers of integrated courses that if they want coherence, they will have to create it. Simply characterizing the disciplines as being too compartmentalized, abstract, and remote from the interests and concerns of most people to serve as a framework for organizing content, and claiming the greater relevance of integrated courses for most students, will not get the coherence job done. The challenge depends to some extent on what approach is being taken to content integration.

Coherence will not be served by inserting little nuggets of science content here and there, for the science must be integral with and woven into the story being told.

If what is intended is the creation a course that connects two or more sciences, as in interdisciplinary courses, the challenge is not to mistake patchwork for coherence. A little physics followed by a little chemistry followed by a little biology, for example, does not necessarily tell a story, or even three little stories. For coherence to prevail, the physics, chemistry, and biology must be woven into a discernable whole that draws on but transcends the coherence that characterizes each of the individual disciplines.

If the intention is to create a course in which something other than science itself is in the foreground—say problem solving or environmental issues—the challenge is to make sure that the science itself does not get lost in the shuffle. A *science* course can be coherent only if the science is there, and not merely in some offhand or emaciated way. Moreover, coherence will not be

served by inserting little nuggets of science content here and there, for the science must be integral with and woven into the story being told.

A new generation of high school science courses is needed that feature both integrated content and conceptual coherence. Once some exist and gain adoptions, careful assessments can determine if in fact better learning occurs—better than in discipline-based courses or than in integrated courses lacking coherence. But of course, the proper measure of "better" is what students learn. Thus, to emphasize a point made earlier, the first and most fundamental step in creating new high school science courses, whether discipline-based or integrated—is to identify a coherent set of explicit learning goals to be targeted. After that, the challenge is for developers to create integrated courses that result in the attainment of those learning goals. The courses themselves should be no less coherent than the goals they claim to serve.

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CHAPTER TWO

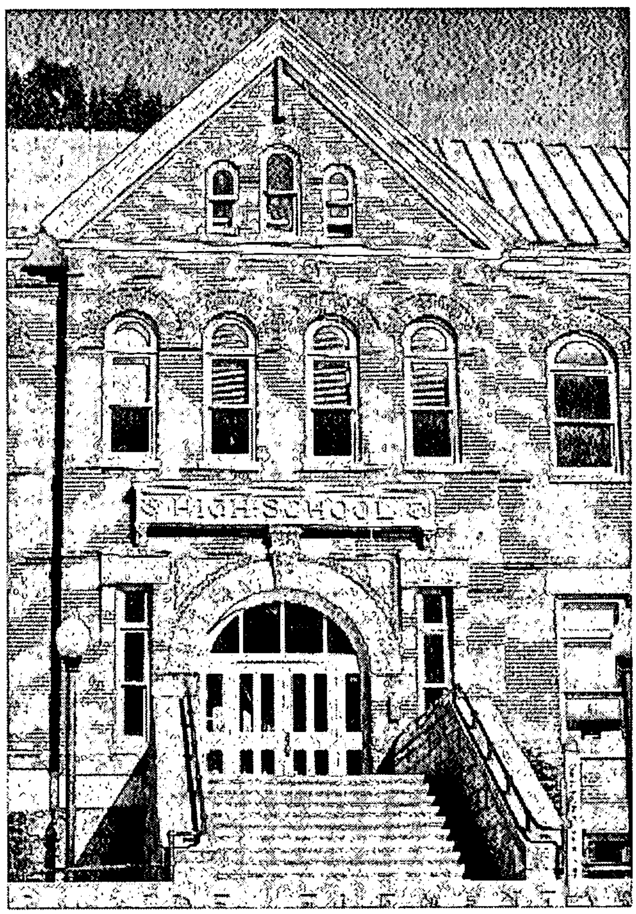
Thinking about Change: What Will It Take to Implement an Integrated Science Program?

In this chapter, we will explore various aspects of schools that influence their capacity for change. In particular, we will consider how the culture of a school influences change. We also will explore the specific changes that are necessary when introducing an integrated science program as well as the specific factors that can limit a school's ability to make and sustain such a change. The two invited essays in this chapter address two major issues related to the introduction of an integrated science program: professional development and assessment.

THE CULTURE OF HIGH SCHOOLS

If you have had the opportunity to spend much time in other high schools in addition to your own, on the surface many aspects appear similar—students, teachers, classrooms, hallways, lockers, bells, morning announcements. Underneath these shared features, however, is a culture and a pre-

vailing climate, which may be distinctively different from school to school and region to region. The subtleties of this culture are not always apparent or likely to surface during a cursory visit. But if you spend a week, talk with students and teachers, attend classes, engage in discussions in the faculty lounge, and attend a school board meeting, you may have a better feeling for the culture of the place and the current climate. The culture and the climate of a school will have a tremendous effect on the degree of success that a school might experience with a significant change such as the implementation of an integrated science program.



One way to gauge a school's likelihood for success with change is to look at its overall characteristics. John Goodlad (1994) describes seven underlying characteristics of good schools—intrinsic characteristics not academic ones. Assessing your school with respect to these characteristics may provide a broad picture of the culture and climate of your school, and thus help you gauge its capacity for change. We first present Goodlad's characteristic and then a related question you might ask about your school and district.

1. A good school is good in virtually all respects.

   How do the teachers, students, administrators, and parents characterize your school?

2. Good schools tend to enjoy district support, and conditions of the school district itself impinge upon the quality of individual schools.

   How does the district characterize and support your school? How do you characterize your district?

3. A good school is self-conscious of its culture.

   How aware of the school's traditions and character are the various stakeholders?

4. A good school takes care of business. Processes of dialogue, decision making, taking action, and evaluating these actions are built into the culture.

   How effectively does your school community take care of the business of dialogue, decision making, taking action, and evaluating its progress?

5. A good school seems to have come to terms with external standards by developing an internal sense of its educational role and the importance of academic work.

   How does your school deal with external standards from the larger community? What is your school's internal sense of its educational role and the value of academic work?

6. A good school is characterized by an array of positive human connections.

   How would you characterize the quality of human connections and relationships within your school—teachers to students, teachers to teachers, students to students, administrators to teachers, and administrators to students?

7. A good school is connected to homes and parents in positive ways.

   How would you characterize the quality of the connections between your school and homes and parents?

If your school embodies most of these characteristics, it is likely that your school would have a high capacity for change. If, on the other hand, your school embodies only a few of these characteristics, change is likely to be more challenging.

Schools As Cultural Systems

It is helpful to view schools not just as a set of characteristics, but as cultural systems. As such, these systems are made up of a network of important relationships among teachers, students, administrators, and the greater school community. The health of these relationships within the system determines the overall health of the system and consequently its capacity for change. Will this cultural system and these relationships support change—is it a system where the relationships are open, supportive, and responsive? Or will this cultural system make change difficult—is it a system where the relationships are ill-defined and tenuous? Is the climate a relatively positive one, with satisfied teachers, students, and parents? Has the school or district had recent successes or a string of failures? Is there a sense of pressure or of collective purpose?

The culture and the climate of a school will have a tremendous effect on the degree of success that a school might experience with a significant change such as the implementation of an integrated science program.

The salient relationships in a school system include those of the teachers with students, students with other students, teachers with other teachers, teachers with administrators, and students with ideas. A school system also comprises a set of processes—those of policy making; the day-to-day formalities and the day-to-day informalities; the process of celebrating successes and of addressing problems; the process of honoring students and teachers; the process of honoring traditions that sustain the health of the system and that of changing traditions that no longer support the system. Taken together, the salient relationships and processes contribute to the cultural system of a school.

Too often, even though we may use the word *system* to describe a school, in reality, we view it not as a dynamic, living system, but as

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a machine system with interchangeable parts. It is not surprising then that some feel you can make changes by changing the parts. Meaningful change, however, does not usually occur by changing the parts, but rather by making changes in the nature of the relationships and the processes within the system. Successful change is most likely to occur by introducing the change within the context of the relationships and processes. Because relationships and processes form an intricate web, the effect of a change in one part of a living system has an effect on relationships and processes throughout the system. The level of resolution has an important effect on the success of the change too. If the proposed change seems to be valuable only at one level of resolution (for example, at the level of the school but not at the level of the teacher or student) then wholehearted buy-in to the change is less likely. It is critical when considering a change such as the implementation of an integrated science program to look at what it offers to relationships throughout the system, at all levels.

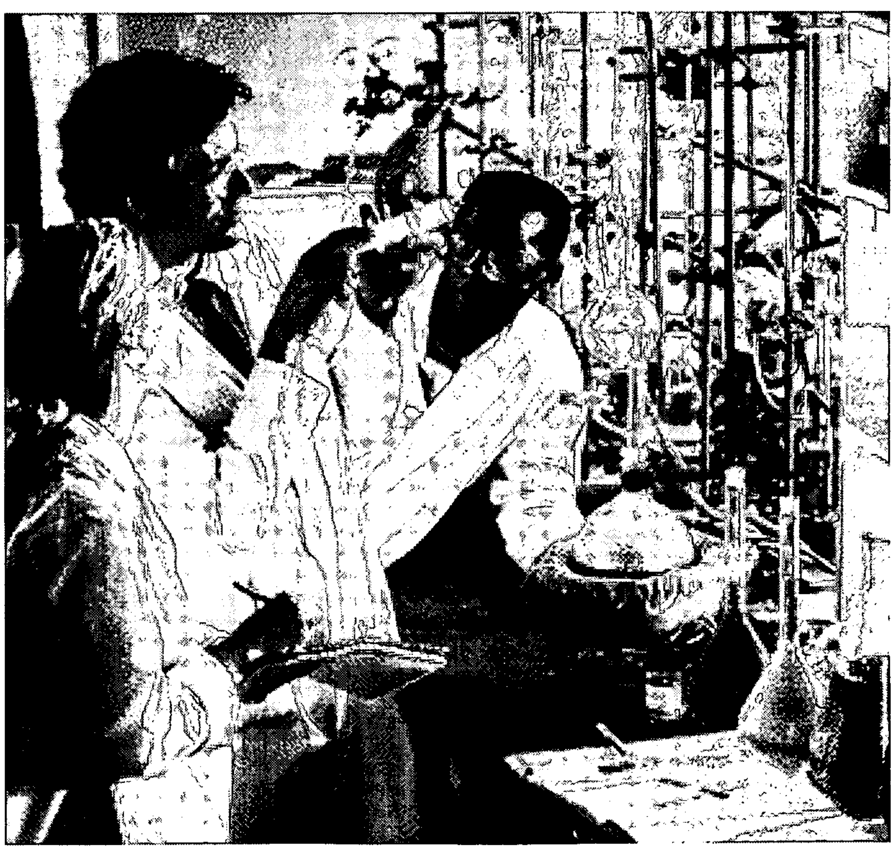
Even though we may use the word system *to describe a school, in reality, we view it not as a dynamic, living system, but as a machine system with interchangeable parts.*

A larger issue that also impinges on the cultural system of a school is the prevailing nature and current reality of school reform at the policy level. Although we will not address this policy level in-depth, it is critical to realize that conflict and contradictions at the policy level trickle down to relationships and processes at the level of the school and affect the culture and climate. Although the education community speaks of systemic reform and holds it in high esteem, many such reform efforts eventually translate into linear, task-oriented approaches that lose sight of the system—of the interrelated webbing of relationships and processes. Linda Darling-Hammond (1993) suggests that currently there are two contradictory theories of school reform—one that focuses on outlining broad, sound educational goals and finding direct, efficient ways of meeting them and another that focuses on capacity building in teachers and administrators to increase participation more broadly in inquiry-oriented, collaborative organizations. Conflict between such theories at the policy level creates tension and uncertainty at the level of the school. And, as John Goodlad (1994) points out, it is difficult for schools to create positive changes when the fundamental prerequisites for such change are not in the school's control.

Change Requires Participants and Participation

An important observation about systems and change, which comes from the natural sciences, is that systems often change as a way of preserving themselves. When applying this observation to a system such as a school and a change such as the introduction of an integrated science program, we see the potential dilemma. If the participants in the system do not see the necessity of change for the sake of their own preservation, they are not likely to be engaged in the change and the change is not likely to be sustained: Change requires participants and participation.

In addition, change is more likely to be successful if the proposed change helps the people within the system become more of who they are and embody more of what they feel is meaningful. In this way, change happens from within the system. Change that is forced on a system from the outside, and that may not seem meaningful to the individual participants, is less likely to be sustained. State mandates and sweeping, district-level decisions may fit this category.



Teachers are natural agents of change because of their position in the heart of the system and their level of autonomy in the classroom. Within limits, teachers can be catalysts of significant changes that begin in their classroom. A classroom provides a realistic testing ground for new ideas. When ideas are successful, teachers can refine them, expand them to other classrooms, and take them to the administration for broader support (see the California Scenario in Chapter 4). Within a district or region, we see pockets of highly successful integrated science programs for reasons such as these.

If a particular school has a principal with a high interest in integrated science, he or she is likely to hire teachers who do also. Innovative schools and principals build on their reputations and attract other participants who are of like minds. If some of the current teachers at the school have less interest in integrated science, they likely will leave to find a school where the approach to science is more traditional. It is also true that principals who are less interested in change often surround themselves with teachers of like minds, so that the status quo is more likely to continue. Such schools still may be good schools in many respects, but are not likely to have a very high capacity for change. The opposite scenario happens as well. If a particular teacher is interested in participating in innovative changes such as an integrated science program, but finds him- or herself in a very traditional school environment, that teacher is likely to seek out a new school setting that matches his or her own goals.

Teachers are natural agents of change because of their position in the heart of the system and their level of autonomy in the classroom.

Factors That Limit Change When Introducing Integrated Science Programs

When considering the introduction of an integrated science program, the relationship we are most concerned with is the relationship between the student and the science content. Schools that are planning such a change usually are doing so because the teachers and administrators think that integrated science may be an effective way to engage more students in science and strengthen their relationship with the science content. With this in mind, then, it is important to examine how schools and districts can best support the teachers in

this process. It seems especially critical to support the teachers' relationships with valuable resources such as time, money, supplies, curriculum materials, and professional development opportunities.

Time is one of the most critical resources for all professionals, and teachers are no exception. Teachers ask, "Where will I find the time to do all the work that is required when implementing an integrated science program?" Teachers who are successful with change generally are extremely self-motivated and are willing to put in the extra hours that are needed. For others teachers, the motivation is strong, but additional incentives help. When administrators recognize the teachers' reality and support teachers as they work to introduce integrated science, this support is felt throughout the system. When principals provide more release time for course work at a nearby college or university and when principals further accommodate teachers by suspending some of their other time-intensive duties, teachers are more motivated to participate fully in the change.

Closely related to time is the issue of scheduling. When principals are able to create a positive environment and accommodate the need for collaboration among teachers, this infuses the system with positive energy. Specific support, such as an extra planning period, joint planning periods with other teachers, or block scheduling that allows for longer science classes, contributes to the experience of integrated science. Teachers recognize and value these concrete gestures of sup-

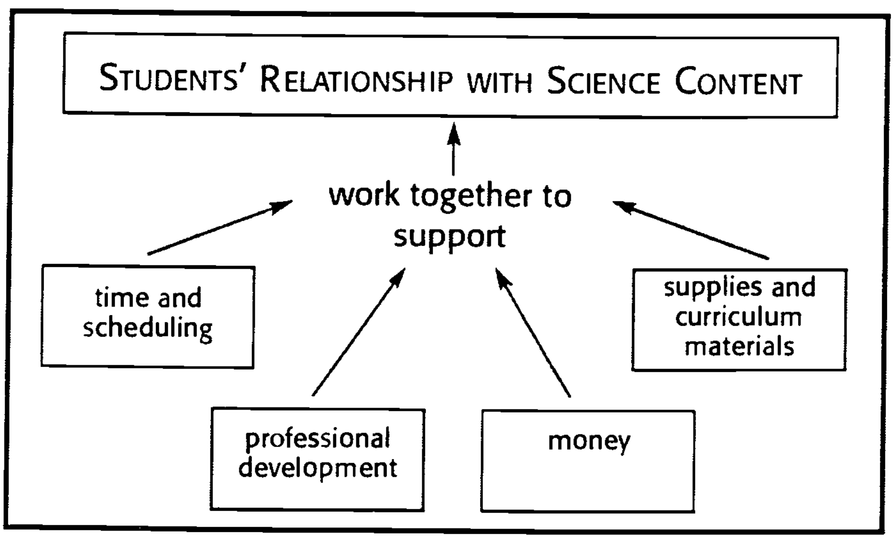


Figure 2.1 The students' relationship with science content is supported by the teachers' relationship with time, professional development opportunities, money, and curriculum materials.

port. Such actions not only eliminate hurdles, but provide incentives and scaffolding for the success of the program.

Money is often the flip side of time. Funds always are important at the beginning of any major change in a school science program, especially those that require additional schooling for teachers, new curriculum materials, new supplies, and other professional development opportunities. It is most helpful if districts and principals are active in pursuing funding well in advance of the implementation so that teachers can prepare academically and pedagogically for the change in a reasonable time line. In some districts, special funds are budgeted for such implementation efforts. In many districts, Title II funds can be used to support a range of professional development activities. Districts also should plan to submit proposals to a number of federal and state agencies involved in education as well as to local industries as a way of obtaining additional funding and training. District personnel also should develop effective working relationships with local institutes such as colleges and universities.

When administrators recognize the teachers' reality and support teachers as they work to introduce integrated science, this support is felt throughout the system.

In addition to the obvious need for strengthening teachers' science content knowledge in the disciplines outside of their major field, other areas of professional development that are important to integrated science programs include in-depth training in the use of innovative curriculum materials, experience with instructional strategies such as team teaching, a focus on inquiry, investigating local issues, and assessment strategies. Attending to these important concerns of teachers is likely, in turn, to have a positive effect on the students' relationship with the science content.

Many issues about change and professional development related to integrated science are addressed in the essay by Rodger Bybee and Susan Loucks-Horsley, which follows this section. Integrated science also presents challenges with respect to assessment strategies. If we are changing our approach to instruction, we also must change our approach to assessment—that is, our approach to assessment must align with our approach to instruction. How, then, will we assess learning in integrated science? This is the topic of the final essay in Chapter 2.

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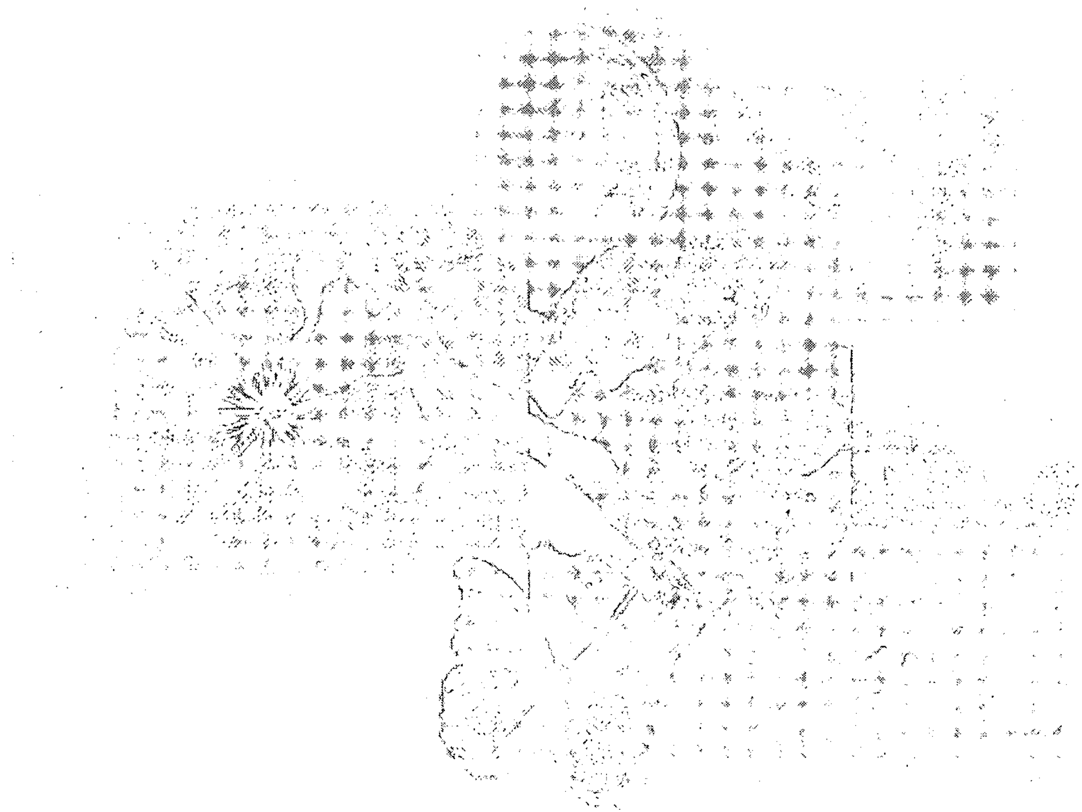

Supporting Change through Professional Development

Invited Essay by
Rodger W. Bybee
Susan Loucks-Horsley
Biological Sciences Curriculum Study

Facilitating Change

Implementing an integrated science curriculum requires change for teachers: change in knowledge, skills, attitudes, and teaching strategies. It also requires change in school structures, norms, and relationships. Change is not easy, so knowing something about the change process can help those who work with teachers (for example, administrators and coordinators) to learn, use, adapt, and incorporate the new curriculum into their teaching. Effective change requires determining what teachers need and how to meet those needs as they make the changes necessary to implement an integrated science program.

The concerns expressed by teachers as they experience a change provide valuable insights about ways and means of helping them with curriculum implementation. A research-based model, the Concerns-Based Adoption Model (CBAM) helps predict those concerns (Hord, Rutherford, Huling-Austin, & Hall, 1987). The CBAM is based on four assumptions. First, change is a process. Curriculum implementation takes time and attention. It does not happen overnight. Second, change occurs in individuals first, then in organizations. Teachers need attention first, then the district, school, or department. Third, change is a personal experience, one that strikes people in different ways. Although one teacher may easily accommodate a new program, the teacher next door may have difficulties. This may be due to different skills, preferences, and backgrounds. Finally, while different people respond differently to change, there are predictable stages that people seem to go through as they learn about, try out, master, and refine new programs—both in how they feel about the change and in what they actually do. The CBAM

incorporates these stages; knowing where people are in the process can suggest the most appropriate ways to help them. For details on how this model might relate to the implementation of an integrated science program, refer to Appendix A.

FOUR ASSUMPTIONS ABOUT CHANGE

- Change is a process.
- Change occurs in individuals first, then in organizations.
- Change is a personal experience.
- People experience predictable stages during change.

Source: Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987).

WHAT ARE THE IMPLICATIONS OF INTEGRATED SCIENCE FOR SCHOOLS AND SCIENCE TEACHERS?

We do not suggest that introducing integrated science into the school curriculum will be easy. An integrated science curriculum is very different from a traditional science curriculum and requires a considerable amount of forethought, planning, and support. An integrated approach, by definition, suggests that there will be a wide range of learning outcomes and instructional strategies. For example, outcomes of integrated science include subject matter, inquiry abilities, and understanding technology, history, nature of science, and social issues. Instructional strategies may include inquiry-oriented activities, historical case studies, reading, research on the Web, and other uses of educational technology.

Professional development is required for new curricula to be used well. Although this idea is far from new, another research finding is more so: New curriculum materials appear to be effective vehicles for teacher learning.

Thus, implementing an integrated science curriculum is not as simple as replacing the current chemistry course with a new one. Nor is it as easy as purchasing a new biology textbook. The challenges of implementing an integrated

science program may parallel those experienced by the Earth Science Curriculum Project (ESCP) in the late 1960s and early 1970s. With ESCP, the science education community introduced a new subject into school science programs. This challenge was complicated by the fact that few teachers were actually prepared to teach earth science, much less an activity-based program.

Similarly, with integrated science, there first will be a need to establish a place for it in school science programs, one that aligns with graduation requirements. This suggests the need for a program designed for all students in grades nine, ten, and eleven. Second, few (if any) teachers are actually prepared to teach or have experienced an integrated approach to science. So the program will require a thorough set of teacher resources and background materials. Finally, because most teachers will be teaching out-of-field for some portion of the program, successful implementation will require thorough and continuous professional development. We address these challenges in the remainder of this chapter.

Connecting Professional Development and Curriculum Implementation

In Appendix A, we suggest the kinds of support teachers require if they are to thoughtfully and effectively implement a change as large and complex as an integrated science curriculum. Here, we elaborate on one area of support, teacher professional development, and its critical link to curriculum, in particular, to an integrated science program.

Recently, researchers and practitioners have identified two important ways in which new curriculum and professional development are symbiotic. First, in order for teachers to use new curricula well, especially those materials that incorporate the ambitious content and teaching requirements of national standards, they need opportunities to learn new knowledge, skills, and approaches to instruction. Professional development is required for new curricula to be used well. Although this idea is far from new, another research finding is more so: New curriculum materials appear to be effective vehicles for teacher learning. By studying new materials, using them in classrooms, examining the thinking and the products of students who interact with the materials, and sharing their observations and dilemmas with others, teachers can strengthen their understanding of content, of student learning, and of effective teaching strategies (Ball, 1996; Cohen & Hill, 1998; Russell, 1998). Professional development based on and using new, reform-oriented curriculum materials such as integrated science can

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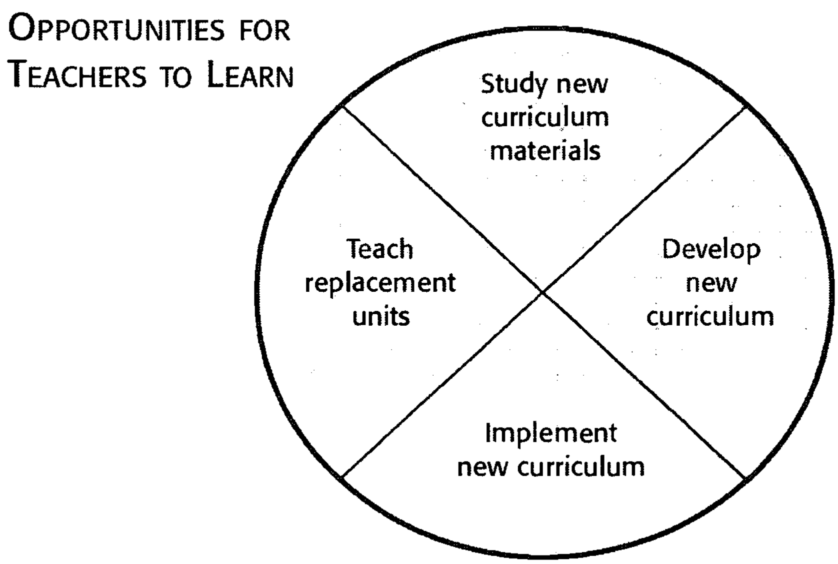
provide students with a variety of ways to learn science that focus on fundamental understandings and skills. At the same time, their teachers learn more content and more effective ways to teach.



Professional development in integrated science provides teachers with opportunities to learn.

In the recent book *Designing Professional Development for Teachers of Science and Mathematics*, Loucks-Horsley and her colleagues described fifteen strategies that are being used successfully to help teachers learn; three of these strategies link to curriculum. One of these strategies, curriculum development, can help teachers learn in situations where appropriate curriculum materials do not exist, or where teachers have the expertise, time, and resources necessary to develop their own. Another strategy, the use of replacement units, helps teachers learn how to teach a new way or teach content that is new to their curriculum by trying a series of lessons and then reflecting on their experiences. This strategy is especially helpful when no full set of curriculum materials exists, when a small foray into a new approach to teaching and learning is called for, and/or when units are being purchased and introduced one at a time for economic reasons. The third strategy, curriculum implementation, is most relevant when discussing the use of a full set of curriculum materials, such as an integrated science program.

Curriculum implementation uses different kinds of professional development as teachers' concerns change and as their knowledge and skills change as well. Early in implementation, professional development using a workshop format can help teachers learn "how to do it" from those experienced

in using the curriculum. Through experiencing the student activities as a learner, teachers learn the content they will teach their students. For some who learned science as a set of facts and principles to be memorized, they learn what a big idea (fundamental science concept) is and how facts fit into conceptual understanding. They also experience how it feels to learn through an inquiry-based approach. They learn to explore ideas through materials before being told. They learn to develop explanations for what they observe and defend their explanations using evidence. They learn to challenge each other's ideas in an educational context and to report on their own ideas in ways that communicate effectively.

Through experiencing the student activities as a learner, teachers learn the content they will teach their students.

These early workshops address management issues: What materials are needed, how to manage them, how they work, what is apt to be troublesome. Teachers develop some comfort from knowing they have the "cookbook" to consult when and if they need it.

In effective workshops, teachers learn to wear two hats: that of a learner and that of a teacher. They practice doing science through the student activities and reflecting on what and how they are learning. Then, they learn to step back and view their experiences as a teacher. What ideas did they struggle with? What helped them in their struggles? What ideas are their students apt to struggle with? How can they discover what is hard for their students to learn and what is not? How can they help their students with their struggles? Discussions of these questions go beyond management to consequence concerns. In a series of workshops on a new curriculum, the emphasis can usually shift from issues of management to issues of student learning, but must do so gradually and as teachers' management concerns become resolved.

These activities in initial workshops prime teachers to teach the new curriculum units. In the most supportive settings, they have coaches who visit and look for ways to help them make their classroom and materials management smoother; they have opportunities to share their successes and solve problems with other teachers, including those experienced in using the curriculum.

Professional development changes when management concerns decrease and teachers can focus on instructional practice. Strategies for teacher learning include examination of student work, case discussions, and action research (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Teachers can bring student work to share that raises questions for them. (For example, What does her

student understand about energy in ecosystems? How can I help my students realize the role of inquiry in the study of science? What are the current conceptions of these students? Other issues that student work may illustrate include the development of inquiry abilities and the use of technology in science and in school programs.)

Similarly, they can view a video from one of their classrooms or from a video collection, write and share teaching cases or read cases that have been developed by others, and talk about student learning and teaching issues that these stimulate. The use of both video and narrative cases is increasing as evidence accrues of their value for teacher learning (Barnett, 1998; Schifter, 1996).

Finally, teachers can engage in action research by identifying a question of keen importance to them in their classroom (for example, Do I treat boys differently from girls? What would happen if I grouped students a different way? How well do students apply science concepts to social issues? Do students understand the nature of science? Do students develop inquiry abilities and understandings in an integrated program?). Science teachers can systematically gather and then analyze data and apply what they learn to improve instruction. These three strategies help teachers focus on student learning to improve how they use the new curriculum in their classrooms.

Immersion experiences develop teachers' inquiry skills and help them understand the nature of science—both critical goals of the integrated science program they are using with their students.

As teachers gain experience in using an inquiry-oriented curriculum, they often acknowledge a hole in their background: that they have never themselves "done" science, that is, actually conducted a scientific investigation from beginning to end. Their interest can lead them in two directions: to professional development institutes and workshops that immerse them in inquiry or to internships in research organizations. Professional development institutes held by science museums or other "informal" science organizations challenge teachers to identify questions of interest, design investigations, gather data, create explanations for patterns in their data, and integrate these explanations with those they learn from scientists, scientific literature, and the Web. Internships in science research organizations give teachers the opportunity to work elbow-to-elbow with scientists on research teams, which allow them to discover the wide variety of ways that scientists work and scientific knowledge is produced (Hays, 1994). These immersion experiences develop teachers' inquiry skills and help them understand the nature of

science—both critical goals of the integrated science program they are using with their students.

Professional development deepens and broadens teachers' abilities to use an integrated science curriculum well. By tuning into teachers' needs and helping them expand their experience base, these professional development opportunities can sustain the changes that delivery of a new curriculum program can begin.

Contemporary reform of science education has encouraged innovative approaches to address the achievement of students. Particularly at grades nine through twelve, integrated approaches to science have received increased support. Implementing this innovative change in science education mandates a linkage between curriculum implementation and professional development.

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How Do We Assess Learning in Integrated Science?

Invited Essay by
Kathy Comfort
California Systemic Initiative
Assessment Collaborative

Science Assessment: Why Is It Important? What Should Be Assessed?

In this era of standards-based reform, the definitive questions are still being raised:

- What is science literacy?
- How can we determine if students are achieving science literacy?
- What must students know, do, and understand in science in order to be scientifically literate?

The release of the National Research Council's (NRC) *National Science Education Standards* in 1996 and the American Association for the Advancement of Science (AAAS) Project 2061's *Benchmarks for Science Literacy* in 1993 represented the national consensus of the science education community about what is important for all students to know, do, and understand in science. These reports helped to illustrate science literacy and set the course for standards-based reform. As defined by the *Standards*, science literacy is the command of scientific concepts and processes required for personal decision making, economic productivity, and effective participation in civic and cultural affairs. We can determine whether students are progressing toward science literacy by assessing all aspects of achievement: scientific understanding of the natural world, understanding of the discipline and utility of science, and students' opportunity to learn (NRC, 1996).

As the primary feedback mechanism in the educational system, assessment communicates the goals that students, teachers, schools, and districts are expected to achieve—what teachers should teach and what students should learn. Assessment also provides schools and districts with input on the effectiveness of their teachers and programs and offers policy makers data on how well their policies are working (NRC, 1996).

Assessment should provide students with the opportunity to demonstrate conceptual understanding of the important ideas of science; to use scientific tools and processes; to apply their understanding of these important ideas to solve new problems; and to draw on what they have learned to explain new phenomena, think critically, and make informed decisions. In short, when students engage in assessments they should learn from those assessments (NRC, 1996).

Many schools, districts, and states across the country have been working hard to implement the recommendations of the national standards. (In this essay, "national standards" refers to both the *National Science Education Standards* and the *Benchmarks for Science Literacy*.) Standards-based reform efforts, such as the National Science Foundation's (NSF) Systemic Initiatives (SI), have been instrumental in developing and implementing district and state core curriculum frameworks and standards aligned to the national standards. Many of these same initiatives also have been instrumental in increasing the number of science courses required for graduation and in restructuring the high school curriculum to include both integrated and coordinated science courses. In California, for example, the Los Angeles Urban Systemic Initiative has been working to implement ninth-grade integrated science in all high schools, and the NSF-funded SPAN project has been working with several middle and high schools across the state to implement coordinated science in grades eight through twelve.

However, due to the political focus on implementing and assessing basic skills, very few of these same districts have been able to develop or purchase standards-based science assessments to systematically assess student performance and provide data on the effectiveness of their programs. As a result, many continue to use publishers' norm-referenced science tests, though the tests fail to match either the content of their own state standards or restructured curricula, or the content of the national standards.

Current research has established that assessment plays an important role in standards-based reform (Baker & Linn, 1997). However, unless assessments are systemically valid—aligned to the recommendations of national standards, grounded in the educational system, and congruent with the goals

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and aspirations for all students—they cannot serve as a focus of reform (Bernauer & Cress, 1997).

Educational reformers agree that assessment and instruction are two sides of the same coin—that an invisible thread connects assessment, curriculum, and teaching in the service of learning.

Assessments are used for different purposes within different levels of the educational system. External assessments, such as those administered at the state and national levels, are usually intended for accountability purposes—to audit the performance of teachers and schools and to formulate and monitor policies. In many cases, these mandated external exams do not match the content of the curriculum, district learning goals, or national standards and can have negative effects on instruction (Airasian, 1988). Perceived as "high stakes," they induce teachers to devote significant amounts of instructional time to preparing students to excel on tests that fail to yield meaningful outcomes (Shavelson, Carey, & Webb, 1990). Teachers cannot use the data from these external measures to guide instruction and to help change practice. Nor can they use them as models to design similar assessments at the classroom level to support their instruction.

Internal, or classroom, assessments are usually developed, administered, and scored by classroom teachers because they are in the best position to put assessment data to powerful use. In implementing the vision of the national standards, classroom teachers engage in continuous formative assessment of students' scientific understanding and reasoning and use data to improve student learning, develop self-directed learners, report student progress, plan curricula, guide instruction, and improve and research classroom practice (NRC, 1996). Additionally, current research demonstrates that formative assessment is an essential component of classroom work and that its development and use can raise standards of achievement for students (Black & William, 1998).

The expectations conveyed in the national standards, that all students be afforded the opportunity to become scientifically literate, call for assessment to meet the full range of goals for science education (Atkins & Coffey, 1999). Educational reformers agree that assessment and instruction are two sides of the same coin—that an invisible thread connects assessment, curriculum, and teaching in the service of learning. Not only do good assessments match exemplary instructional practices and serve as a vehicle for learning, they also assess what is important and valued, not just what is easily measured.

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If Schools Are Implementing Integrated Science, Then How Might It Be Assessed?

To implement the recommendations of the national standards and to better prepare students to become scientifically literate citizens, many high schools are restructuring their academic programs to include new courses designed to integrate or coordinate conceptual connections between and within the scientific disciplines. As pointed out in Chapter 1, integrated science often focuses on broad themes and unifying principles that provide a rich context and a creative learning environment and present students with opportunities to explore cross-discipline concepts and solve cross-discipline problems. Because this integrated methodology emphasizes the unifying principles of science, which reflect the cohesive reality of the natural world, it makes science more real, relevant, and vitally connected to the lives of students. Additionally, we learn from Chapter 1 that integrated science is often effectively taught through problem- and project-based approaches that blur the boundaries of individual scientific disciplines, allowing students to investigate a broad range of concepts.

To best assess student achievement in integrated science, it would appear that a variety of instruments, aligned with the core content recommended by the national standards, would be best to measure students' ability to demonstrate understanding of the concepts that are connected and integrated among the sciences. According to Atkins and Coffey, "Assessments that resonate with a standards-based reform agenda should reflect the complexity of science as a discipline of interconnected ideas and as a way of thinking about the world."

In addition to proving the critical importance of teacher involvement, research also has shown that involving students in classroom assessment can increase their achievement.

These standards-based, integrated science assessments could consist of a balance of measures that could be used at the classroom, district, state, and national levels. However, it should be noted that for such assessments to be successfully developed, administered, scored, and reported, there must be congruence between their structural elements at all levels of the system: national, state, district, and classroom. It is also crucial to maintain a balance between theory, research, and practice. Integrated science assessments should promote growth, be dynamic, and be grounded in the "real classroom."

Teachers are central to implementing the vision of the national standards and to keeping curriculum, assessment, and instruction closely linked. As the figure below shows, their position in the classroom allows them to use assessment in powerful ways for both formative and summative purposes (Atkins & Coffey, 1999). Teachers must have the opportunity to collaborate with scientists, measurement specialists, and researchers on the development of assessments at all levels of the system if changes are to occur in their beliefs and practices as well as in student learning.

ASSESSMENT USES

- self-reflection
- monitoring achievement for individual students
- gauging levels of engagement
- reporting to parents
- making decisions about the placement of students

ASSESSMENT USES

In addition to proving the critical importance of teacher involvement, research also has shown that involving students in classroom assessment can increase their achievement (Black & William, 1998; Fuchs & Fuchs, 1986; Fuchs & Fuchs, 1997). Therefore, students should be provided opportunities to reflect on and evaluate their own work; assist in the design of criteria and rubrics for scoring their work; score the work of their peers and provide constructive criticism; and assist in establishing levels of performance that contribute to a common understanding of what constitutes good work. Participation in assessment also can provide students the opportunities to reflect on what they are learning and to make coherent connections within and between subject areas (Wiggens, 1989).

Instead of pop quizzes, end-of-chapter tests, or standardized norm-referenced exams, integrated science assessments could take on a variety of formats. Additionally, depending on the assessment, students could work individually, with a partner, or in a small group. Assessments could be informal, on-the-spot evaluations or they could be administered within one class period. Extended projects, investigations, and portfolios could take from one month to one semester, allowing students to conduct their own research

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and explore concepts in depth. Students also could keep instructional or laboratory portfolios from which they select their "best work," which might later become part of an assessment portfolio.

Assessment Strategies for Integrated Science

- semester-long projects or investigations
- portfolios
- presentations
- science journals
- interviews and observations
- performance tasks
- paper and pencil tests, including constructed response investigations, open-ended questions, and thematic-conceptual or enhanced multiple choice questions

In one possible scenario, an eleventh-grade integrated science student works with three other students to conduct a semester-long investigation focusing on solving a "real life" problem—global warming, for example. This assessment could be designed to measure the students' ability to use scientific processes and tools, communicate thinking processes, and demonstrate understanding of concepts that are connected and integrated among the earth, space, and life sciences.

As part of the investigation, the students have the opportunity to formulate hypotheses and questions; make and record scientific observations; gather, manipulate, and analyze data (their own, other students', and from databases on the Internet); formulate and revise explanations and models; discuss and defend their ideas with other students, their teacher, and visiting scientists; incorporate mathematics and technology in the development of data charts and graphs; analyze their conclusions based on their findings; and use their scientific knowledge together with what they learned from the investigation to make recommendations for solving the problem.

Throughout this extended investigation, students collect in their laboratory portfolios multiple forms of evidence such as notes, drafts, data, observations, reflections, essays, formulas, charts, graphs, and responses to questions. Their

teacher provides feedback and conducts an ongoing assessment of their work throughout the semester. Then, in order for their teacher to evaluate their overall effort, the students select from their laboratory portfolios their five best entries, representing their understanding of the connections among the earth, space, and life sciences, along with a rationale as to why they think these are their best pieces. The students receive scores for their individual work as well as a group score for their overall effort.

The teacher scores each student's five entries with a rubric. The teacher also provides each student with feedback, along with a profile of scores. The scores are mapped onto standards of performance that the teacher and students developed at the beginning of the project. Students receive a copy of these standards at the beginning of the semester to help guide their investigation. Each student's assessment portfolio also contains his or her self-evaluation plus evaluative comments from peers, all of which are reviewed, but not scored, by the teacher.

There is a serious discrepancy between the current methods of accountability and the recommendations of the national standards. Currently available, off-the-shelf, standardized, norm-referenced tests fail to match the content and recommendations of the national standards.

In another hypothetical case, a teacher prepares to administer a standards-based science assessment to her tenth-grade integrated science students. In conjunction with other classroom teachers, scientists, science educators, and measurement specialists on a national science assessment committee, the teacher has participated in the development of the assessment. Because it is available in both English and Spanish, all students in her class are able to participate. The assessment takes two to three class periods to administer, and its components are aligned to the content recommendations of the national standards. Moreover, and most importantly, the assessment integrates and coordinates science concepts. Specifically, components consist of the following:

- Hands-on Performance Tasks These tasks provide students the opportunity to construct the big ideas of science through inquiry and investigation. Performance tasks are presented to students with a story line that identifies a problem to solve in the investigation. The story line is based on themes, such as evolution or energy, that weave together the coordinated ideas of science into a coherent unit of study. Students perform a

series of three or more coordinated tasks from life, earth, space, and/or physical science. Students use hands-on equipment and perform short experiments, make scientific observations, generate and record their data, and analyze their results based on their data. Additionally, performance tasks require students to use their scientific knowledge to move beyond the task and apply both new and previously gained information to solve a problem. Students record their data and responses in a test booklet that teachers score later using scoring rubrics.

- Constructed-Response Investigations These investigations are similar to performance tasks but do not require hands-on equipment. Students are presented with a problem that students in another class or school are trying to solve. The problem is featured in a story line that coordinates concepts from the disciplines of science. Students are provided with data sets and questions. They must analyze the problem, conduct a secondary data analysis, revise a hypothesis, construct questions, suggest other models, and recommend solutions. Students record their responses in a test booklet that teachers score later using scoring rubrics.

- Open-Ended Questions These are nonmultiple choice questions that encourage students to think critically, solve problems, and communicate possible solutions. Presented with a problem that coordinates ideas from the different scientific disciplines, students are requested to write a short essay or to manipulate data about the problem. Responses are recorded in a test booklet that teachers score later using scoring rubrics.

- Enhanced Multiple Choice (EMC) and Justified Multiple Choice Questions (JMC) EMCs contain a cluster of two or three coordinated and/or integrated (physical, earth, space, and/or life science) items interwoven by a theme(s) embedded in a short story line. These questions assess students' understanding of important scientific facts, principles, laws, and theories and probe analytical reasoning skills. Students record answers on a scannable answer sheet. JMCs are similar to EMCs except that students must also compose a short note of justification. Written responses to the JMCs are scored by teachers using scoring rubrics.

- Opportunity-to-Learn Surveys These surveys are designed to collect student responses similar to those in the National Assessment of Educational Progress (NAEP). These questions address the type of science (life, earth, physical, integrated, or coordinated) being learned; how it is being learned (textbooks, demonstrations, investigations, and so on); the time spent on homework in science compared with other subjects; participation in science fairs; and the use of technology.

After students complete the standards-based assessment battery, the teacher returns all materials to a designated test contractor. The contractor

processes all materials and scores the multiple choice items. The scoring of the performance components of the assessment will be conducted as a professional development activity in conjunction with teachers, science educators, scientists, and measurement specialists. Teachers are trained in the scoring process and in calibrating scores to the criteria in the scoring rubrics. Current research has shown that the scoring of student work in collaboration with colleagues helps teachers clarify their teaching goals, learn more about national and state standards, enrich their scientific knowledge, learn more about students and their work, and develop insights to support their teaching (Falk & Ort, 1998).

Once all student work is scored and analyzed, it is reported back to the teacher according to the content categories of the national standards and the integrated concepts identified by the teacher. This reporting strategy allows students and schools to measure students' growth against the content recommendations of the national standards instead of comparing them with each other.

What Are Some of the Issues and Challenges Associated with the Assessment of Integrated Science?

First and foremost, there is a serious discrepancy between the current methods of accountability and the recommendations of the national standards. Currently available, off-the-shelf, standardized, norm-referenced tests fail to match the content and recommendations of the national standards, nor are they aligned to the standards, curriculum, or classroom assessments of schools attempting to reform science education. Additionally, instead of comparing student performance against a set of standards, they focus on comparing the performance of student groups against each other. These tests cannot serve as a vehicle for measuring progress toward science literacy set forth in the national standards. Yet, many districts and schools implementing integrated science programs persist in using these norm-referenced tests to measure student achievement and progress. If the goal of integrated science programs is to prepare students to become scientifically literate citizens, then schools and districts implementing these programs must invest in valid and reliable standards-based assessments that will provide them with useful and meaningful information about students' understanding of integrated science concepts.

The issue of the misalignment between current assessments and standards-based programs leads to a challenge—the challenge of developing standards-

based assessments that will support integrated and coordinated science at different levels of the system. A very small number of states and districts has been able to develop and implement science assessments that are aligned to the recommendations of the national standards, and even fewer has access to integrated or coordinated science assessments. The challenge is ratcheted up a notch when these same assessments are expected to address both traditional and integrated or coordinated science courses. Additionally, the development of assessments that are "naturally integrated" or coordinated is not an easy task.

Unless issues such as professional development, time, resources, and support from school and district administration are adequately addressed, teachers' ability to use assessment in the service of student learning will be seriously compromised.

For example, in 1992 the assessment unit of the California Department of Education field tested both integrated and coordinated science performance tasks at grade eleven as part of the state testing program. The team responsible for the assessments found the development of the integrated performance task to be more daunting than the development of the coordinated performance task. Although the team was able to "stack" the different disciplines of science side by side in the coordinated task and connect them into a coherent unit with themes, team members found it difficult to naturally integrate concepts from the life, earth, and physical sciences into an integrated task. Part of the difficulty with the integrated task was the team's definition of "integrated." It was operating under the premise that all integrated tasks had to address the disciplines of life, earth, and physical science equally. For this specific task, team members succeeded in meaningfully integrating two of the three sciences (earth and physical sciences); however, they were not able to comfortably include a third discipline (life science). The third discipline, life science, became an obvious "add on." As a result, the task was difficult for students to understand and for teachers to administer and score. Consequently, the team decided to change its definition of an integrated task from having to equally integrate the life, earth, and physical science, to one containing a combination of disciplines that would harmonized more naturally—eliminating "forced fits."

The administration and scoring of the coordinated performance task, on the other hand, was more successful. Working in triads, students were presented with a problem and an array of evidence that required them to orchestrate their understanding of biology (using a microscope to investigate properties

of different samples of hair), chemistry (conducting a chromatography test to determine who wrote a note), and earth science (conducting profiles and pH tests on samples of soil) to investigate a potential crime scene. Each of the three tasks, representing a different discipline of science, was woven together by a thematic story line. The tasks yielded scores in life, earth, and physical science as well as an overall score for conducting an investigation.

In line with the challenges associated with assessments for standards-based integrated and coordinated science is the assessment capacity of classroom teachers. As mentioned earlier, teachers are at the forefront of implementing science reforms, yet they have little, if any, training or preparation in assessment development, administration, scoring, and use of results. Additionally, unless issues such as professional development, time, resources, and support from school and district administration are adequately addressed, teachers' ability to use assessment in the service of student learning will be seriously compromised.

As stated in the introduction to this guide, it is evident that current high school science programs lack the rigor and depth necessary to provide students the opportunity to meet the recommendations of the national standards and to become scientifically literate citizens. In response, science educators across the country are thoughtfully restructuring high school science courses from the traditional sequence of earth science, biology, chemistry, and physics, to ones that will integrate content knowledge across the disciplines. Therefore, conceptually coherent curricula and assessments, carefully aligned with instruction, professional development, and other important policy elements, will become key performance indicators for schools, districts, and states that are striving to meet these challenging needs.

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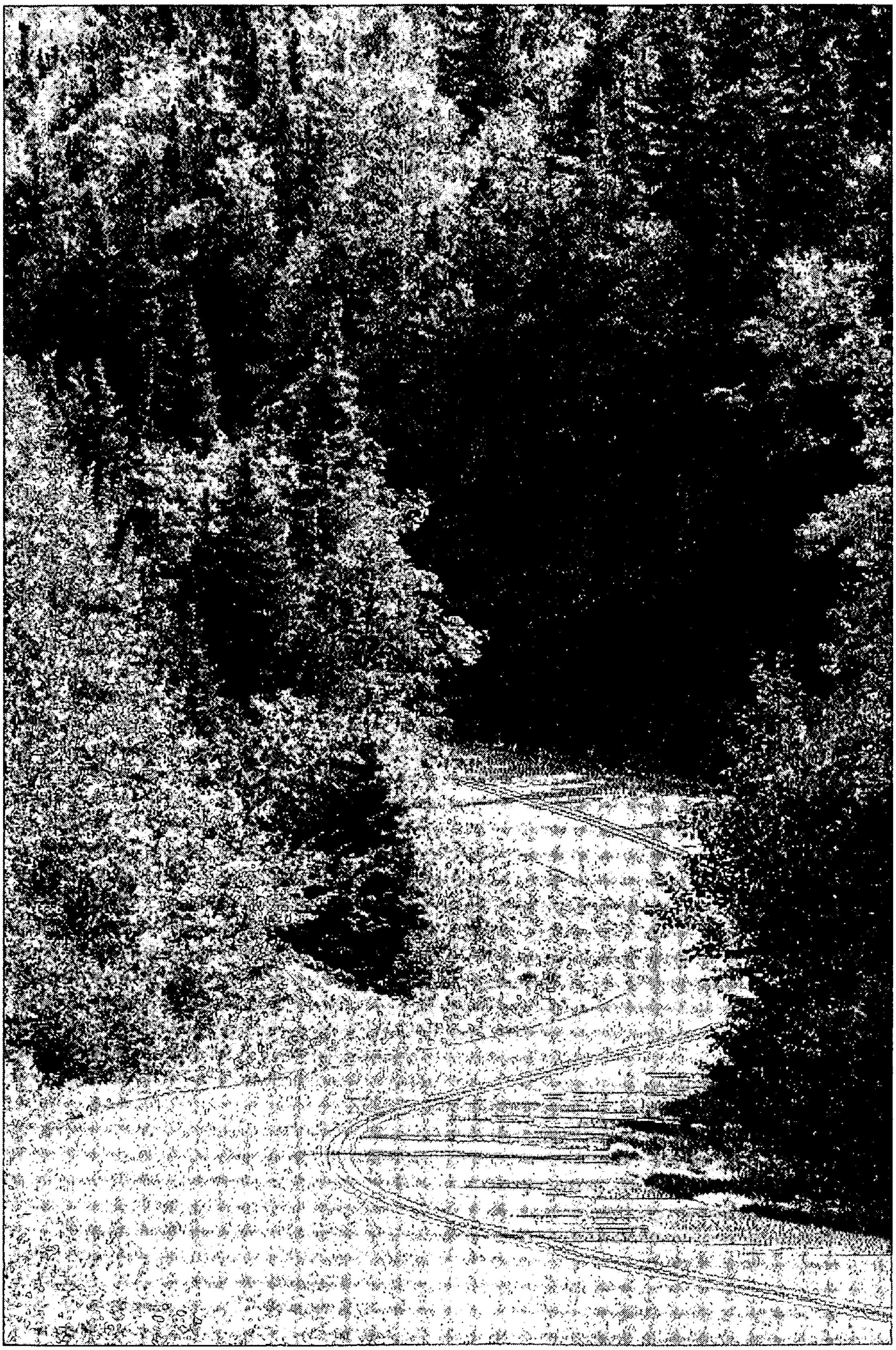

CHAPTER THREE

Thinking about Implementation: The Road Ahead

LOOKING AHEAD

By now, you have a good idea about what integrated science is and the range of ideas that contribute to it. You also probably are more aware of some of its rewards and challenges. Now it is time to consider how a school or district might go about implementing an integrated science program—from decision making (which model do we want to implement?) to planning for successful implementation. The process we describe here is ideal in many respects, and given constraints within your district, you will need to modify the process accordingly. If the real adventure of implementation takes you down a slightly different path, we expect that many of the ideas we present here still will be of value. We know the landscape is varied and the paths are many. The road map that we provide can be used to navigate along the major pathways; you may find short cuts, detours, and scenic byways that better suit your needs. You also will find that on

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a philosophical level, if not a practical level, some of the ideas we ask you to examine will contribute in both subtle and perhaps striking ways to your own professional development and that of others.

When thinking about substantial change in a school science program, it is important to consider the big picture, one that includes a somewhat distant horizon.

Much of this chapter addresses the implementation of a comprehensive program in integrated science; that is, a program with a large grain size, for example, Model V or VI. If your district, school, or you as an individual teacher are considering integrated science programs with a smaller grain size—for example, Model III or IV—the process could be scaled back considerably. A scaled-back version for an individual teacher or group of teachers considering Model IV is described in Appendix B. If Model III or IV best represents your case, it still may be useful to read through this chapter and consider the steps that seem appropriate for your task and your setting.

A Framework and a Perspective

When thinking about substantial change in a school science program, it is important to consider the big picture, one that includes a somewhat distant horizon. In particular, for integrated science, it is important to keep in mind issues that we presented in Chapter 2 that have to do with the educational climate, the culture of schools, and the readiness of various stakeholders for change. It also is important to have a framework for guiding the work of change. One such framework that seems particularly useful is presented here (see Figure 3.1). This framework provides a structure within which your leadership team can conduct its work.

The three phases of the circle in Figure 3.1 represent three major processes: Reflecting, Planning, and Taking Action. Reflecting involves assessing current attitudes of your own and others, clarifying your purpose for seeking change, setting overall goals, and making a decision about what you want to do. Planning involves setting detailed goals that align with your decision, crafting a realistic time line for meeting your goals, and establishing criteria by which you can measure success. Taking action naturally involves a commitment to the actual work and carrying out the work. A feature of the

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framework that is important to keep in mind is its recursive nature—the process is not strictly linear. As you reflect on your work, for example, you will revisit your goals and plans as well as establish new goals and plans for various subsets of your work.

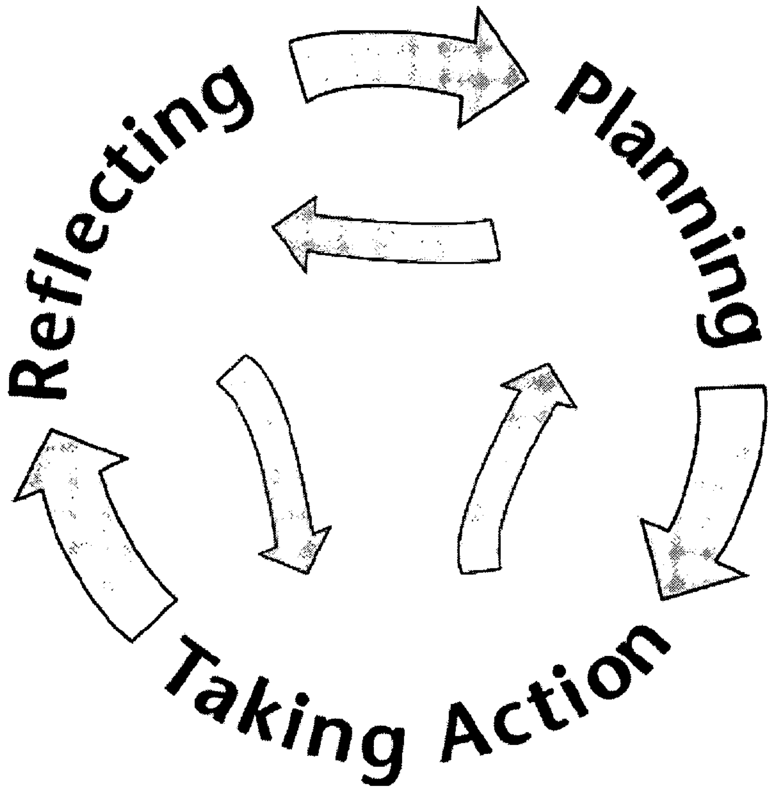

Figure 3.1 The major components of a framework for change include reflecting, planning, and taking action. The process is somewhat fluid and recursive.

The framework can be used to structure the overall work as well as smaller subsets of the work, and this same framework is useful for tasks at several different levels of resolution. It can be used broadly at the district level to guide a range of work that involves organizing and mobilizing groups of people in planning and taking action. It can be used at the school level to guide the implementation process within a single school, and individual teachers also can use it as a tool to monitor their own professional growth. In this guide, at the largest resolution of the overall work, we focus on reflecting and planning. Many of the details of taking action (the ongoing work of implementing change) will be the focus of additional work at BSCS.

The catalyst for change in schools and districts likely will vary, and some will find the process smoother than others. From our experi-

ence, if the processes of reflecting, planning, and taking action have both structure and flexibility, then implementation has the greatest chance of succeeding.

Some Guiding Principles

Some of the principles of Open Space Technology, a strategy for leaders developed by Harrison Owen (1997), may be beneficial to your work—especially to your team processes. Owen developed his approach after reflecting on two simple observations he had made in different parts of the world. The first observation he made numerous times in this country. Like many of us who attend conferences on a regular basis, Owen noticed that often the most insightful and effective conversations occurred during the coffee breaks, lunch breaks, walks to and from meeting rooms, and other informal settings in the midst of the formal structure of the meetings themselves—that is, they happened in the open spaces and open times. Owen's second observation came from his work in a number of villages in West Africa. Owen observed that these communities have an informal social mechanism for resolving community issues. Individuals who wish to raise an issue that concerns them do so in the central, open marketplace. Other members of the community, hearing the concern, gather to voice opinions and find resolutions to the issues.

If the processes of reflecting, planning, and taking action have both structure and flexibility, then implementation has the greatest chance of succeeding.

The salient principles of this open-space approach for meetings and for the practice of leadership are simple: (1) Open the space and the time for people to share their ideas and (2) Hold that space open until the work is completed. Using these principles, people feel their ideas are valued, know it is safe to voice concerns, are usually able to develop a shared vision, believe that the real issues get addressed, and find the solutions are lasting.

Reflecting

An overview of one process of reflecting and decision making is first outlined here and then expanded on. You may want to vary the steps to fit your particular needs and address the particular concerns of

your stakeholders. This structure is not meant to be prescriptive, but rather a place to begin and then adapt as you go. As outlined, the process is quite lengthy, and given your specific constraints of time and energy, your leadership team may need to modify the process accordingly.

An Outline for Reflective Decision Making

1. Convene the district leadership team to oversee the decision-making process.
2. Review the district's current goals for science education.
3. Establish a set of overall goals for the work of the team.
4. Craft a work plan for meeting the team's goals and evaluating the success of meeting those goals.
5. Complete initial information-gathering tasks so that the team is able to make well-informed decisions.
   a. Carry out a broad-based needs assessment that includes responses from both individual stakeholders and groups of stakeholders.
   b. Analyze the results of the needs assessment.
6. Reflect on the results of the needs assessment through a series of dialogues.
7. Consider the need for more information and plan to gather it to inform your discussions.
8. Develop a list of the top three options for integrated science in your district or school along with the strengths and weaknesses of each option.
9. Discuss each option.
10. Select the best choice for your district or school.

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Convening a Team and Gathering Information

The initial step when considering the implementation of an integrated science program is to put together a strong district leadership team to oversee the process. To be most effective, this leadership team

This leadership team is the foundation of all the work that will follow, and it needs to be developed with care and staffed with people who will value the work.

should include representatives from each group of stakeholders in your district. These stakeholders include teachers (both new teachers and teachers with more seniority), principals, district science specialists or curriculum specialists, school board members, parents, students, and a district-level evaluator. Sometimes the catalyst for change comes from the district level and sometimes it is a grassroots effort, and decisions that involve changes in high school science curriculum and course offerings may be made at a range of levels. You should have a clear understanding about where such decisions are made in your district and have those decision makers represented on your leadership team from the beginning, if yours is a grassroots effort.

This leadership team will guide the district and schools through the process of change, and because of this role, it is important that each team member be able to thoughtfully represent his or her role in the school community. It also is important that all team members are committed to working together to develop a shared vision. If the team is not committed to a shared vision, the work will be difficult and may be ineffective. This leadership team is the foundation of all the work that will follow, and, consequently, it needs to be developed with care and staffed with people who will value the work.

First, it is valuable for the leadership team to reflect on its mission and establish goals and objectives for the team itself. This may help ensure that the team will contribute in the most effective ways as it helps the school community meet the district-level goals for science education. The team also should set one overarching goal that it has for students. Often revisiting this student-centered goal during lengthy discussions or in times of confusion will help the team stay focused. The leadership team also should develop a time line for reaching its goals as well as an evaluation plan for measuring its progress and its success.

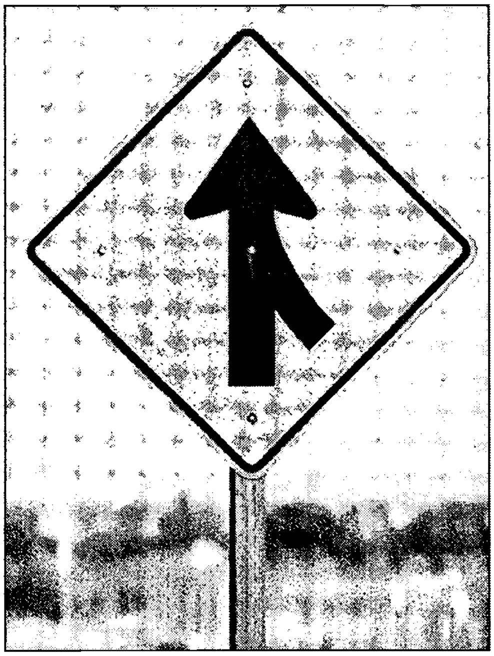
As part of the early work, the team should review the district's current goals for science education. Questions to consider during this review process include the following:

- Do the goals reflect what we want our students to know and be able to do in science?
- Do the goals reflect what we value about science education?
- Do the goals reflect what we value about science?
- Do the goals reflect what is best for our students?
- Do the goals represent excellence in teaching?
- Are our goals aligned with national standards in science education?
- Are our goals aligned with state and district frameworks for science?

After reviewing these goals, team members should discuss whether there is a need to revise these goals based the district's evolving vision of science education or whether the goals broadly represent what the district values. You may find that a slight or perhaps major revision of the goals is in order, which then becomes the first task of the team. Such a task may be within the authority of the team to pursue, or it may require special action by the school board. Once the team has a shared vision for the broad goals of science education in its district, the foundation on which to build the new works is in place.

It is important to understand and address the concerns of all of the stakeholders in order to get the broadest and most realistic vision of "where you are" and to ensure the greatest likelihood of success in implementing an integrated science program and getting "where you want to be."

To make the most well-informed decision possible about integrated science, it is important to gather the thoughts of many of those involved in science education at the high school level. A needs assessment is a valuable tool with which to collect these thoughts in a systematic way. Such a tool will help your district leadership team determine where the various groups of stakeholders in your district are with respect to different aspects of science education, where they want to be, and to what extent your school community is prepared to change. The results of this needs assessment will help your leadership team make thoughtful decisions, plan, and carefully prepare for



the most effective change. It is important to understand and address the concerns of all of the various stakeholders in order to get the broadest and most realistic vision of "where you are" and to ensure the greatest likelihood of success in implementing an integrated science program and getting "where you want to be."

We have developed a needs assessment that contains a database of questions for each group of stakeholders (see Appendix C). The leadership team should review the range of questions in each category and select from them a specific set of questions to use. It would be most efficient to develop your needs assessment from the Rich Text File (RTF) of this document, which is available from the BSCS Web site (www.bscs.org). From the RTF file, you can copy and paste the selected questions into another file to create your own needs assessment.

The team should be careful to select questions that it feels will cover both the general and specific concerns in your district. The team may want to adapt some of the questions if a particular phrase would make more sense for your district's circumstances. In addition to adapting some of the questions, team members may want to add a question or two that addresses specific concerns of certain stakeholders. We also provide optional sets of questions that you might want to ask additional groups of stakeholders, such as the business community and the university community.

After you have agreed on the set of questions for each group of stakeholders, it would be ideal to pilot each section with a small subset of representatives of that group. It then would be beneficial to bring the entire pilot group together after they have completed the survey individually to debrief their experience with the questions. Following this exchange and input of ideas, you may want to revise your survey in a number of ways. We realize that most school dis-

tricts may not have enough time to do this small pilot, but we mention it for those who find it possible.

The team is now ready to conduct the survey with a representative sample of each set of stakeholders. After you have individuals in each group respond to the survey, organize primary focus groups for each set of stakeholders. Ask members of these focus groups to discuss the questions on the survey and then develop a consensus response to each question. For each focus group, have one member of the district leadership team act as facilitator to guide the discussion. It may be useful to have a professional from your community (an "outsider") perform the role of facilitator if you think it may be difficult to reach consensus. Again, during this phase, the principles of Open Space Technology may contribute significantly to the outcome of your work.

When you have completed both the individual and group surveys, the district evaluator on your team can help you analyze the results. It will be important to analyze the individual and group surveys separately.

Arriving at a Decision

After the team has completed the needs assessment and the analysis of the results, you can plot the results on a decision matrix, similar to the one provided in Figure 3.2. This exercise provides a simple, visual impression of where you are with respect to where you want to be and may be a useful tool in guiding discussions.

This matrix may or may not be an accurate predictor of the likelihood of success in implementing an integrated science program, but it serves as a good beginning point for the next level of reflective discussions. Your leadership team can proceed by discussing "Next Step" questions. We provide a core set of these questions in Appendix D; you likely will expand on this set as your discussions unfold.

After discussing the Next Step questions thoroughly during several sessions, we recommend that your leadership team outline a set of realistic options for implementing integrated science in your district or school. Based on your needs assessment and ensuing dialogue, your options might include the following:

1. implementing a theme-based integrated science program for grade nine only (Model V) or

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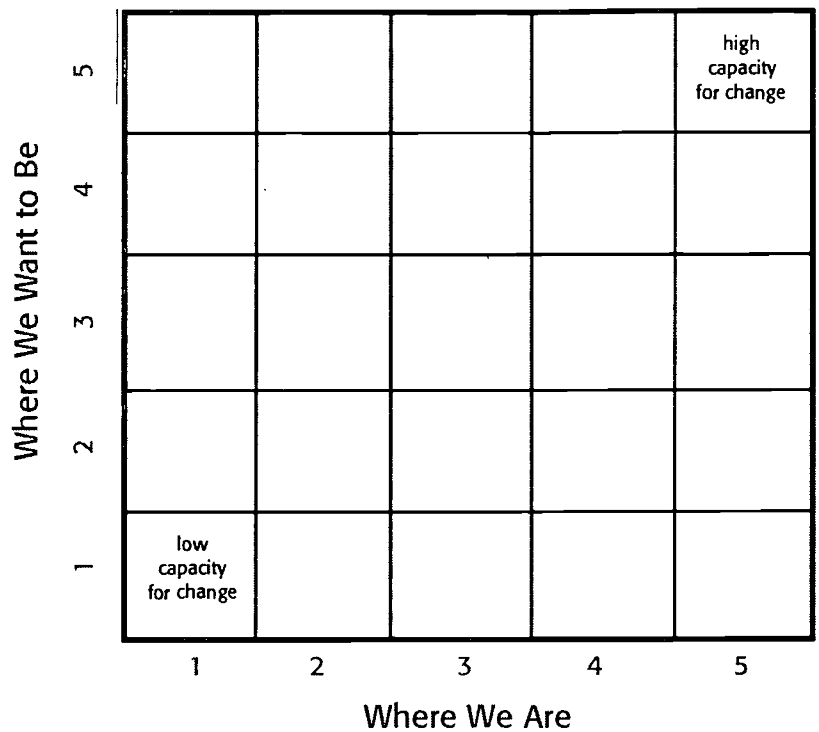

Figure 3.2 A matrix such as this may help you visualize where you are with respect to where you want to be. You can plot the averages of answers from each set of stakeholders and color-code them for easy reference.

2. implementing a three-year, fully integrated science program for grades nine to eleven using a spiraling, thematic vehicle (Model VI).

Once you have specific options on the table, your leadership team should

1. list the advantages and disadvantages of each option with respect to the students and learning, the teachers and teaching, and the district's goals for science education.
2. consider which option offers your district or school the most coherence in its science program.
3. consider which option best aligns with state and district standards and curriculum framework.

Following these focused discussions, the team should select one option as its highest recommendation. Depending on the structure of your district, the actual decision makers for this level of change

may be the school board, the superintendent, or the district leadership team itself. If necessary, your next step would be to arrange a meeting with the decision makers and present your case.

Planning and Taking Action

After your district or school has made the decision to implement an integrated science program following one particular model or variation thereof, then the work of the district leadership team intensifies and the base of the work expands.

Use the framework presented in Figure 3.1 at a smaller resolution and begin with a new cycle of reflecting, planning, and taking action as you plan for and begin implementation. The Concerns-Based Adoption Model (Hord et al., 1987), which is referred to in the invited essay "Supporting Change through Professional Development" and outlined in detail in Appendix A, reminds us to pay attention to the concerns of stakeholders during the process of implementation.

First Steps

Early on in the process, you also will want to put together a small community advisory council for science education if you do not already have one in your district. Your community advisory council, made up of perhaps seven to nine people, will be able to

- provide you with a community-level perspective,
- offer advice when needed, and
- help establish community resources that will benefit teachers and students.

The concept of a road map reminds us that the process of change is, in fact, a journey.

Such a council should be made up of professionals in the community (perhaps from business, industry, or colleges and universities), science teachers, principals, and parents. The principles of Open Space Technology seem particularly valuable with groups such as this, which are somewhat self-organizing and which include a diversity of stakeholders.

If the decision to implement an integrated science program is a districtwide decision that involves more than one school, then it is

important that each high school involved in the process of change establish its own school leadership team. Such a team should comprise three or four people including teachers (perhaps a new and a senior one) and a principal or assistant principal. This new team

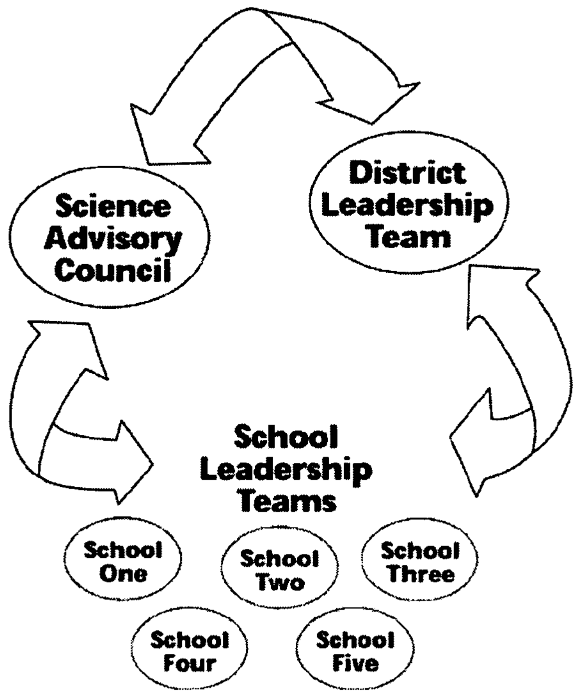

Figure 3.3 During implementation, this system of teams and the relationships within and between the teams will be important.

would serve the school in much the same way that the district leadership team serves the district. This school-based team needs to establish at the outset a process for monitoring implementation, evaluating its effectiveness, and responding appropriately to these findings. Figure 3.3 presents the system of teams that is designed to support critical relationships throughout implementation.

For the purpose of implementation, it may be helpful to consider the notion of a road map. Such a notion reminds us that the process of change is, in fact, a journey. First, when implementing change, there are many points of departure and decisions to make at each new crossroads. Second, the concept of a map will help you think about where your school or district is with respect to integrated science programs and where your school or district wants to be. Third, the concept of a map will help you keep track of which set of stakeholders is most concerned about which set of issues at specific points

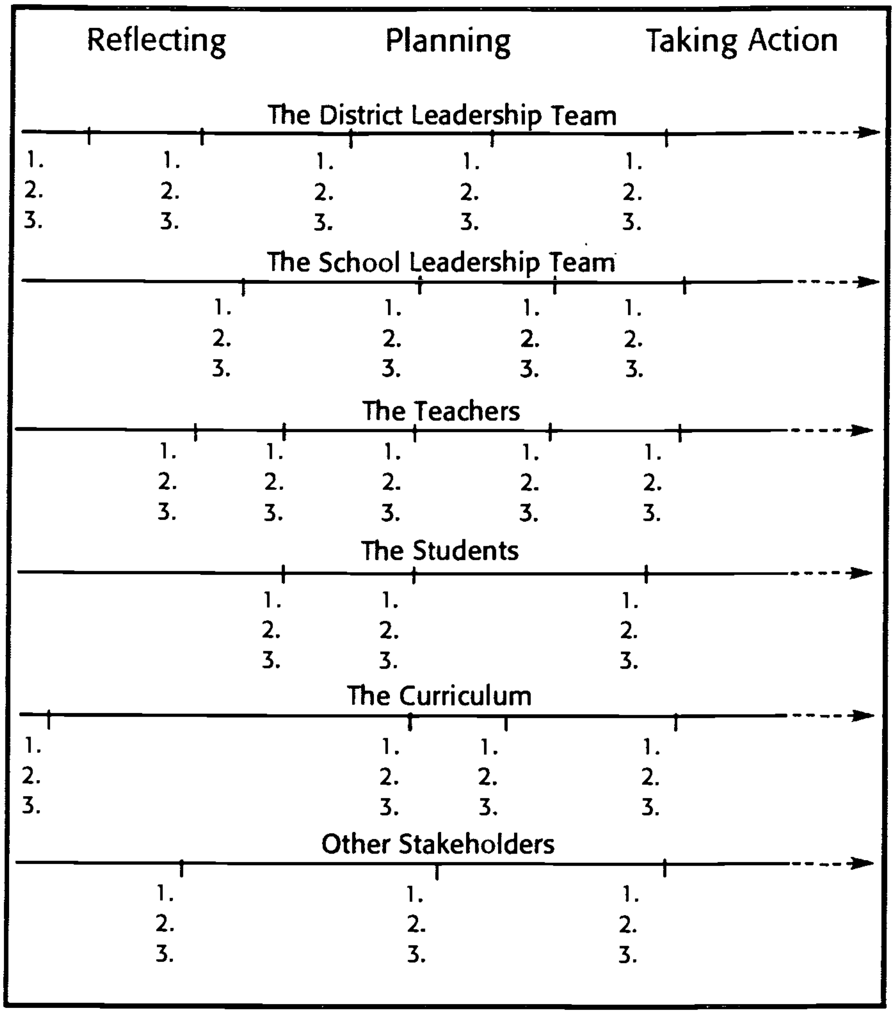

Figure 3.4 A road map such as this may be helpful to your school and district leadership teams as they keep track of their tasks and concerns.

along the way. Lastly, a road map may help remind you of the vastness of the landscape and provide satisfaction in being able to measure successes even on a small scale. You may want to produce a large-scale version of the road map that we provide in Figure 3.4 and display it on the wall during meetings. If you create the map on flip chart paper or other material that you can easily write on, then you can record new ideas and issues along the way.

At this point, the major role of the district leadership team is to support and monitor the implementation process for two main stakeholders: the students and the teachers. Throughout the implementa-

tion process, the needs of students and teachers must remain in the foreground. Generally, the curriculum occupies the interface between the student and teacher. If the process of implementing the curriculum or major portions of the curriculum itself is not working for the students or the teachers, this will severely compromise the likelihood of a sustained change.

Focusing on the Students

The ultimate goal of science education is to improve students' understanding of science and their appreciation for science. Regardless of the vehicle, it is ultimately for the students that we make any change in our school science programs. The students' needs are a priority. The impetus behind any educational change, including a change in an approach to science teaching, is the expectation that the change will result in improved learning for students. After all, that is what education is all about.

In general, we know from the most successful integrated science programs in the country that the integrated science experience works for students. The three scenarios that we present in Chapter 4 describe three types of integrated science programs. Each scenario represents a school or district at a different point in the process of change, and consequently, the results of the change are still forthcoming. Even so, it is clear that most students enjoy the integrated science experience. It is an approach that helps them make connections—and consequently make meaning—of much of what they experience in the natural world.

The impetus behind any educational change, including a change in an approach to science teaching, is the expectation that the change will result in improved learning for students.

We know, however, from less successful integrated science programs that if the teachers are struggling with the decision, the approach, the content, or the curriculum, then the students' experience is severely compromised. We also know from results of our survey that in cases where the decision-making process did not include teachers and in cases where districts were not able to offer teachers the necessary professional development opportunities to prepare them to teach out-of-field, the students suffered along with the teachers (BSCS survey and personal communication 1997–2000).

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Focusing on the Teachers

The ultimate success or failure of any integrated science program often plays out in the hands of the classroom teacher. If the teacher is personally and professionally committed to integrated science and has the support that he or she needs from the district, the school, other teachers, the students, and the parents, then it is likely that the integrated science program will succeed in that classroom and students will learn science. This ideal requires careful planning, a great deal of support, and a high level of commitment from all stakeholders.

Some of the immediate concerns of teachers can be alleviated by implementing change using a realistic time line.

When the decision is made to implement an integrated science program, the stakeholders who are most affected initially are the teachers. The district leadership team needs to be prepared to address the professional development concerns of teachers in a number of areas:

- Motivation for Change Teachers may or may not be prepared for change—or prepared for big changes. The reasons for this will vary: fear, lack of broad science content knowledge, lack of understanding about the new curriculum, and lack of interest in reform in science education. All of these issues contribute to a teacher's motivation for change. It is clear that without motivation, teachers will not change, or will change very little.

- Content Knowledge Teachers often are not prepared to teach across disciplines in the sciences and feel uncomfortable about doing so. If they lack the content knowledge, teachers often return to very traditional methods of instruction when forced to teach out-of-field.

- Instructional Strategies Depending on the vehicle that is chosen, teachers will need help developing instructional strategies that complement the vehicle. These strategies may include team teaching, cooperative learning, bringing inquiry to the foreground, fostering independent learning by students, and project- and problem-based approaches.

- Assessment Strategies As you recall from the invited essay in Chapter 2, "How Do We Assess Learning in Integrated Science?," assessment strategies often are overlooked when a dis-

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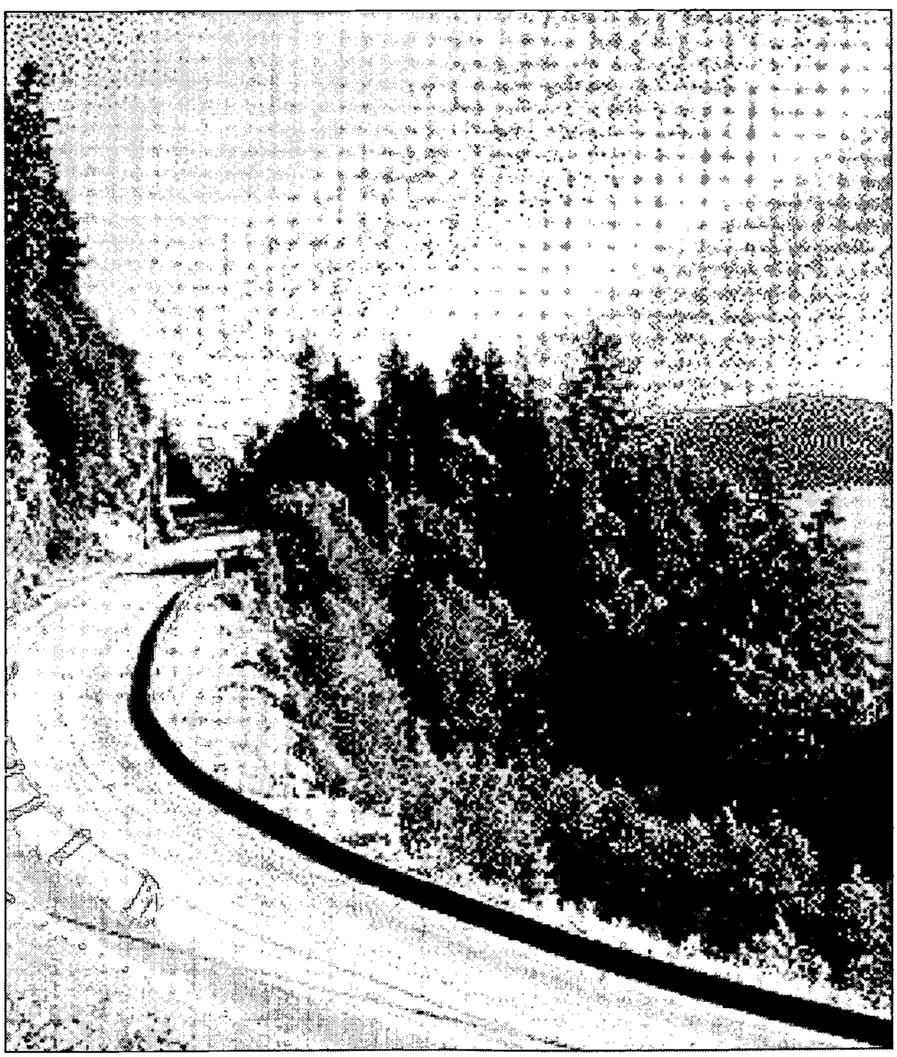
trict or school considers change. The assessment for integrated science may be qualitatively different from assessment in discipline-specific courses. Teachers might need professional development workshops that focus specifically on assessment strategies for integrated science to measure the science achievement of students. Such strategies include effective multiple choice questions, constructed response investigations (essays), hands-on performance tasks, and portfolios.

Some of the immediate concerns of teachers can be alleviated by implementing a new integrated science program using a realistic time line. For example, it would not be realistic to expect that a decision made in the summer of 1999 to implement integrated science would be in effect by the fall of 1999. Ongoing concerns of



teachers can be alleviated to a large extent by having support at the school level, especially from the principal, in the form of both time and resources to attend to each of their concerns. Teachers also need to know that there is district support to address these same concerns.

Professional development strategies that may be particularly beneficial and effective with teachers of science have been described by Susan Loucks-Horsley in *Designing Professional Development for Teachers of Science and Mathematics* (1998). Strategies that may be particularly valuable for teachers of integrated science include:

Strategy 3: Curriculum Implementation;
Strategy 4: Curriculum Replacement Units;
Strategy 7: Case Discussions;
Strategy 9: Study Groups;
Strategy 10: Coaching and Mentoring;
Strategy 11: Partnerships with Scientists in Business, Industry, and Universities; and
Strategy 13: Workshops, Institutes, Courses, and Seminars.

Keeping the Curriculum in Mind

Part of the decision to implement an integrated science program includes, as we have described, a decision about which model of instruction to adopt and which vehicle to use to integrate the sciences. As soon as this decision is made, the district leadership team can better focus its attention on the task of developing the curriculum framework and then finding the instructional materials that best align with the model and vehicle that they have selected. Through a focused effort, the team can develop a framework that best creates a coherent whole, provides opportunities for students to meet the standards, increases students' understanding of core content in the sciences, and makes connections in a meaningful and lasting way.

The district must be prepared to support the change through the purchase of these new instructional materials and the arrangement of the appropriate professional development opportunities for teachers to become comfortable using them.

Evaluating Progress and Sustaining Change

Evaluating the progress and success of change is an important task of the school and district leadership teams. This work is ongoing and dynamic. Initially, as the teams set their goals, they also should develop the criteria they will use for evaluating their success in reaching their goals. These tools should be in place from the beginning and should be used in an ongoing manner. The district evaluator can guide the teams through this process.

As implementation proceeds and new issues arise, the teams should have a mechanism for responding. The team members should find the space and time to share ideas and concerns and create solutions. Each team has the opportunity to develop a forum for creativity that may lead to a number of things—new classroom strategies, new ways of integrating content, and better ways to assess student learning, for example.

The process of implementing an integrated science program offers the opportunity to enrich the landscape with new ideas and to vary the landscape with seeds of change. The opportunity exists to discover new pathways through familiar territory as well as to travel along familiar pathways and find yourself entering new terrain. Sometimes a slightly different landscape, regardless of how you arrived there, presents a distinctively different horizon—a new view that offers many possibilities. Be prepared to take it in.

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Human Anatomy
and Physiology

Chapter Four

How Have Others Done It?

In this chapter, we present detailed scenarios of how actual schools and districts in the nation have implemented integrated science programs. The three scenarios are from different states (California, Utah, and Florida) and represent three different types of districts, each with a different set of concerns and different approach toward integrated science. Some of the incentives and the impetus for change are similar, but the loci of decision, the types of programs implemented, the level of support, and the time line for each have been different.

In the California Scenario, the catalyst for change within the school seems to be the teacher, and most of the initiative for the change is maintained by the teacher. In Florida, the catalyst was at the district level, although the district was responding to a mandate from the state. It is clear that the initiative for change was maintained and supported at

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the district level. In Utah, the incentive for change initially came from the state-level mandate. As you read each scenario, you can see how these different scenarios play out in distinctly different ways. You may find a particular one that closely resembles the situation in your school or district or state. And you may find pieces from each that are particularly relevant.

There also are common threads woven throughout the three scenarios, such as the genuine interest of teachers and professionals in students' understanding of the sciences in a broad and practical sense and the high level of commitment of many teachers to their work. The catalyst for change has some common themes such as the improved learning of science for students.

Having the decision made at different levels and having the momentum for the process of change be maintained at different levels creates a striking difference. You can feel the same level of commitment from teachers in California, Utah, and Florida. The California teacher, on one hand, seems solely responsible for initiating the changes and in sustaining them. She has support from the administration, but only after she proves her point and the program. In

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Florida, the catalyst for the specific changes came from the district, and all stakeholders in the process were involved at each step along the way. Teachers likely felt the support from each other and the district, even though there were individual struggles. In Utah, the catalyst for the specific change came from the state level, and each district or school was left to respond in its own way to the mandate. The support was there, but it was more diffuse.

The catalyst for change has some common themes such as the improved learning of science for students.

It likely will prove useful to study each scenario, consider the plan and the approach, and pay attention to the particular obstacles and the successes. We always can learn a range of lessons from others who are traveling a road ahead of us. You may read the scenarios with interest now and refer back to them on a number of occasions for more information as you find yourself entering new terrain.

Each scenario was written by a teacher, and the Florida Scenario was written jointly by a teacher and a district science supervisor. We felt that the teachers' point of view would be the most valuable for our report. Each scenario was reviewed by someone else in the district for accuracy, but the scenario really represents one person's point of view of the process. See Appendix E for the guidelines the writers used to develop their scenarios.

California Scenario: The Integrated Science Program at Francisco Bravo Medical Magnet High School

BY
Marilyn Perron

Description of School

Francisco Bravo Medical Magnet High School (grades nine through twelve) is designed for students interested in the medical and health professions, although one need not have that goal to attend. The school is located in East Los Angeles in a lower socioeconomic, Hispanic community and is adjacent to several large hospitals, clinics, and laboratories. Seventeen hundred students from across Los Angeles County are enrolled by a random application selection, which is based solely on current Los Angeles County ethnicity balance. Although our school is one of the top schools in the Los Angeles Unified School District (LAUSD), it ranks in the fifty-first percentile on national math and language tests. LAUSD is the second largest district in the United States and struggles with urban and immigrant issues. Bravo, like other magnets in the district, maintains a fairly stable ninth- through twelfth-grade student population with little transience and only minor drug and gang conflicts. The staff, likewise, is fairly stable, and a casual family atmosphere is maintained. In addition to regular state fund-

ing, the nine-year-old school receives $50,000 per year from a trust fund, $400,000 per year from Title I money, and has been partners with local universities in grants of more than $1,500,000 from the National Institutes of Health and the Howard Hughes Medical Foundation.

Description of the Integrated Science Program

Historically, the science program at Bravo has included traditional biology, chemistry, and physics along with physiology and several medical electives such as ophthalmology, biomedical research, and medical lab assistance. These courses are offered along with Advanced Placement (AP) Biology and Chemistry. Remedial and noncollege preparatory classes such as life science were phased out in accordance with the district's attempt to provide a more equitable science education to all students. For several years, certain classes at Bravo were unofficially "remedial" and did not meet our district's course outlines for content or rigor. For example, advanced physical science became a low-level earth science course instead of a rigorous chemistry-physics course, and science fundamentals became a basic math-lab skills class instead of a rigorous senior-level analysis course. As of June 1999, the district has yet to align its standards with the 1999 State Science Content Standards.

Because the State Science Content Standards specify biology, chemistry, physics, earth science, and investigations as separate categories each with several detailed conceptual components, many do not think the mandated state assessments match. The assessments at each grade level (nine, ten, eleven) cover all science disciplines each year. Moreover, because the district requires only two years of science for graduation, a student following the traditional biology-chemistry-physics route does not necessarily take physics, never mind the earth science component. Individual schools can increase the science requirements for graduation if desired, but Bravo has not elected to do so. Each school is allowed to develop its own course of action as long as it uses district-approved courses (or applies to pilot new courses) and is following district and state standards. Monitoring is left entirely to the school site.

Integrated Science Program Overview

The 1999–2000 school year will be the third year of our integrated science program at Bravo. We offer Integrated Science I for ninth graders and Integrated Science II for tenth graders; beginning in September 1999, we offer Integrated Science III as one of many electives for eleventh graders.

During the first two pilot years (1997 and 1998), 240 students, approximately half of our ninth graders, took Integrated I and then Integrated II as tenth graders. One-fourth of the tenth-grade students currently taking integrated science have elected to take Integrated III in the eleventh grade instead of one of the numerous specialized medical or AP classes we offer. These students were originally placed in the integrated sequence primarily because

- they did not make it into honors biology,
- they wanted to be in a specialized hospital-work program that offered only integrated science (by teacher's choice), or
- they did not care and there was space in the classes for them.

Beginning in September 1999, all ninth graders take Integrated I. Biology, except for AP Biology, has been dropped from our offerings. The following year, this tenth-grade class will all be in Integrated II. Some of the highest achievers also will take AP Biology as a second tenth-grade science course. In eleventh grade, these students will take either Integrated III, AP Chemistry, AP Physics, Physiology, Medical Microbiology, Biomed Research, Medical Lab Assistance, Ophthalmological Technician, or other electives added by that time to our program. Our integrated science courses are taught as fully integrated courses with each teacher teaching the chemistry, biology, physics, and earth science components to the same class. Although there are some advantages for students to rotate among discipline-specific teachers as is often done in a coordinated approach, we do not think that such rotation helps most students learn.

The 1999–2000 school year will be the third year of our integrated science program at Bravo.

Our program has been aligned with the 1999 California State Science Content Standards, which are as follows:

- Earth Science
  - Earth's Place in the Universe
  - Dynamic Earth Processes
  - Energy in the Earth Systems
  - Biogeochemical Cycles
  - Structure and Composition of the Atmosphere
  - California Geology
- Biology
  - Cell Biology
  - Genetics

- Ecology
- Evolution
- Physiology

- Physics
  - Motion and Forces
  - Conservation of Energy and Momentum
  - Heat and Thermodynamics
  - Waves
  - Electronic and Magnetic Phenomena

- Chemistry
  - Atomic and Molecular Structure
  - Chemical Bonds
  - Conservation of Matter and Stoichiometry
  - Gases and Their Properties
  - Acids and Bases
  - Solutions
  - Chemical Thermodynamics
  - Reaction Rates
  - Chemical Equilibrium
  - Organic and Biochemistry
  - Nuclear Processes

- Investigation and Experimentation

The vehicles for integration in Integrated I include one semester of an integrated study of water and one semester of an integrated study of the atmosphere. Each semester includes basic concepts from chemistry, biology, physics, and earth science.

In Integrated II, eleven thematic units continue the integrated connection:

- Sound Reproduction
- Controlling Change
- Seeing Inside the Body
- Waste Not—Want Not
- Making Use of Oil
- Sports Science
- Energy Today and Tomorrow
- Burning and Bonding
- The Thread of Life
- All Systems Go
- The Earth in Space

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Due to the medical emphasis in our high school, Integrated III has a physiology-based outline and applies concepts of each of the sciences to the human body. Each concept spirals for Integrated I and II, and many will continue into Integrated III, which is still under development.

Background of the IS Program

With the district eliminating all remedial science courses in order to give all students equal access to science literacy, in the spring of 1996 the science department agreed to try the integrated approach for a two-year trial as a nonthreatening way to deal with the average and below-average student. Above-average students would continue to be scheduled into the traditional biology, chemistry, and physics pathway. But this was not the actual beginning of integrated science at Bravo.

At Bravo, our journey into integrated science began in 1994 when I seriously started investigating in depth the question of how much discipline-specific science knowledge one must accumulate before one could easily make connections between the sciences in order to understand the complex issues in our world.

See "Why Bother?" in Chapter 1 for a discussion of a rationale for integrated science courses.

Even though I have fifty years of life experiences, several degrees, and an energetic curiosity, I still found it difficult to make connections and have a solid understanding of the range of complexities in our natural world. I avoided the "tough sciences" by becoming a biology person! I found it easier to study than to solve problems. The ability to study, however, was not the national indicator of scientific literacy. So for three years, I attended many seminars and workshops sponsored by LAUSD and the University of California—Los Angeles (UCLA). I finally began to understand what it might be like for a high school student to learn what science really is.

Studying *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (NRC, 1996), attending classes at Cal Poly to add a physics supplement to my biology credential, and becoming part of the Los Angeles Systemic Initiative in Math and Science (LA-SI) each contributed to my behind-the-scenes preparation to promote integrated science. During that same time, I also attended business seminars in leadership training.

In May 1996, I recruited a science teacher from our department who had a chemistry-physics credential and was equally committed to the idea that all students could learn all sciences. She was tired of being assigned only ninth-grade classes because the more senior teachers insisted on teaching the chemistry and physics classes. We attended an integrated/coordinated conference sponsored by LA-SI and spent all of our free time pouring over integrated science materials available in our district. "Yes, yes, yes, this is the way to get our kids involved in all the sciences," became her refrain. In September 1997, we began teaching integrated science to half the ninth graders. We each taught four classes and all four science disciplines. We conferred daily during the first semester. She helped me with chemistry, and I helped her with biology. She had an extra work period paid by LA-SI to prepare and organize our integrated curriculum. The students engaged in integrated water studies, several at a local pond.

"Yes, yes, yes, this is the way to get our kids involved in all the sciences," became her refrain.

Unfortunately, during second semester, we both took on additional responsibilities. She became engaged and made plans to relocate, and I became a candidate for National Board Certification. We stopped meeting daily and worked independently in our rooms. Although our courses were still integrated, she began to emphasize the physical sciences.

In 1998, we hired a new teacher to replace the previous ninth-grade teacher who married and relocated to another state. This new teacher also had a chemistry credential and UCLA training in teaching integrated science. I also recruited another teacher from the department to teach the tenth-grade integrated classes. He had been involved in integrated science at another school in 1991 but the program suffered from lack of financial support and lack of appropriate curriculum materials. Another new tenth-grade teacher was also assigned to the integrated classes. She had several years of experience at the Jet Propulsion Lab in Pasadena, California, and she is working toward state credentialing. Initially, she felt that integrated science was for the less-able student. Now, she is supporting our efforts to provide an academically rigorous integrated curriculum.

See "Planning and Taking Action" in Chapter 3 for ideas about a school-based leadership team.

During this second year of integrated science at Bravo, I was paid a work period by LA-SI to coordinate our curriculum, prepare labs, facilitate scheduling of students, and keep the integrated team informed of current reform practices. We met as an integrated team only twice each semester because

each teacher wanted to work through the curriculum for his or her own class. The two tenth-grade teachers met weekly and shared labs as did the two ninth-grade teachers. Although each teacher followed a different time line and frequently implemented the content in a different manner, each teacher covered the same basic concepts from chemistry, biology, physics, and earth science. In addition, the tenth-grade teachers administered the California Golden State Exam in Integrated Science to all of their tenth-grade integrated science students. Results from the exam are pending.

At the end of the second year, the four teachers met to evaluate their integrated experience and to more closely align the curriculum with state standards. We also met with LA-SI staff to discuss the future of integrated science in LAUSD. They are enthusiastic advocates of the integrated approach. During these first two years, our school received $16,000 from LA-SI for materials and time as determined by the integrated teachers. We spent $12,000 on supplies and $4,000 on personnel time for planning curriculum. Once the department saw how the financial support benefited the program, and because we were continuing the traditional biology, chemistry, and physics pathway as well, the department supported this two-year trial integrated project. After the principal and academic guidance counselors were assured that integrated science met the University of California entrance requirements, they too supported the implementation of the two-year trial program.

Initially, she felt that integrated science was for the less-able student. Now, she is supporting our efforts to provide an academically rigorous integrated curriculum.

We planned the full two-year cycle and agreed that we would decide whether or not to continue at the end of this two-year period. At the end of the second year, June 1999, we decided to continue and expand the program so that all ninth-grade students (as of September 1999) take Integrated I and continue the integrated sequence as tenth graders in Integrated II. Integrated III is offered as an elective to eleventh graders.

This decision reflects an 8:4 split in philosophy within the science department. The integrated science teachers responded to a range of accusations and met privately to discuss how to proceed. Although there had been several open meetings to discuss all aspects of the integrated approach during the two pilot years, four teachers never considered the possibility that we

would decide to continue, much less expand. Three of the four were actively involved in the state committee that was developing the State Science Content Standards. They felt that because the State Content Standards were split into separate science disciplines, the courses must necessarily be split that way also. They seemed totally unprepared for the state and district decision to test all students in all the sciences each year, making independent courses an unreasonable and ineffective way to proceed for most students.

As we resolve conflicts within our community of teachers, we will use many of the team-building strategies and attitudes that we are trying to foster among the collaborative student groups within our classrooms.

The timing is perfect for an expansion of the integrated science program at our school. For the current school year (1999–2000), we have hired three new, highly qualified teachers who seem to be willing to break into teaching by teaching an integrated approach. As we resolve conflicts within our community of teachers, we will make use of many of the team-building strategies and attitudes that we are trying to foster among the collaborative student groups within our classrooms. At present, all teachers who will be teaching the integrated classes have decided to give it their best shot. They are determined that, "If it can work, we will make it happen." We are trying to woo the other four teachers. They will have this year to prepare to teach integrated classes, to share the upper-level classes with other teachers, and to share materials and facilities.

See Appendix A for details about a Concerns-Based Adoption Model.

To increase their competency in science content and in inquiry-based science activities, integrated teachers will attend a variety of seminars during the summer as well as during the school year. These workshops are sponsored by local agencies such as the Department of Water and Power and LA-SI, LAUSD, AP College Board, and local universities. All teachers have checked out textbooks in all the sciences to brush up over the summer. In May 1999, all California schools received a one-time science materials grant of $11 per student from the state. Teachers have used this money to purchase integrated supplies needed for this school year. LA-SI is hoping to continue funding for our planning time.

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Concerns of the Stakeholders

Teachers

Teachers who are currently teaching integrated science have this to say about the integrated approach:

- "I love it—it's the best approach for grades nine and ten so that the students understand that scientific laws operate the same no matter what the discipline."
- "Very stimulating to me as a teacher—lets us look in depth at major issues such as global warming, weather, without having to tell students that they will have to wait for their next science class to understand all aspects."
- The comment, "Maybe it's OK for low-achievers," has changed to "Maybe we can make it rigorous enough for access into AP-level courses for those interested in a particular pathway."
- "This time, the district has backed a winner."

In addition, integrated teachers are eager to also teach AP Biology, AP Chemistry, and AP Physics to students who have had Integrated Science I and II because these students will have a clear idea of what the specific science is about and how the concepts relate to the other sciences.

Teachers who are opposed to the integrated approach have this to say:

- "Some sciences are just too difficult for many students to understand."
- "I will never share my equipment or lab facilities with teachers of integrated science."
- "I will never teach an integrated science program . . . it is educationally unsound."
- "Teachers who think they are qualified to teach in an integrated approach are just kidding themselves."

Students

Students in the integrated classes are very eager to participate in the hands-on, inquiry learning. Because the labs are very integrated, the students must think critically about several cross-discipline concepts after they collect data. For example, applying gas laws to weather data or analyzing photosynthesis based on concepts of light and energy transfer prevents the cookbook, fill-in-the-blank, "minds-off" labs. One student summed up the integrated approach with, "This class only asks us to answer the challenging questions." A change in our students' attitudes toward science also can be seen in the make-up of our annual science fair entries. There was a 70 percent increase

in participation among our integrated classes, and, more notedly, for the first time, an equal balance of submissions in all of the disciplines.

Students who are not in the integrated sequence think that it is impossible to learn all four sciences each year and seem to have little understanding of how concepts overlap in the sciences. Students in the integrated sequence are delighted that eventually at least one portion, if not more, of the particular unit will interest them. It remains to be seen if our four students who took AP Biology concurrently with Integrated II will do as well as those students who took biology and then AP Biology as a second-year course. Teachers expect that their AP results will be as good.

At each step, one is reminded that change does not come easily and that the administration may often have to take an active role in enforcing district policy in the school.

At each step, one is reminded that change does not come easily and that the administration may often have to take an active role in enforcing district policy in the school. Integrated II teachers eagerly administered the California Golden State Exam in Integrated Science to all of our Integrated II students in 1999. It is regrettable that the school administration did not see the value in doing a double or triple test (that is, give all Bravo students the same Golden State Exams in Integrated Science, Biology, Physics, and Chemistry this year regardless of the science they took) so that we could get a baseline from the different disciplines. Paired studies of State Stanford 9 science tests for all students showed that those in integrated science improved/regressed at the same level as those in biology or chemistry. The district has no requirement that real analysis be done for testing. We are one of very few schools that even tried to do paired studies for our students. There is little organized effort to plan from our test results, although we are given time as a department to do so. We hope that team collaboration encouraged by LA-SI for the integrated science courses will foster increased teacher-initiated responsibility for student learning.

Parents

Parents have had little to say about integrated science. This is due, in part, to the fact that it has been only in the past year that Bravo has seriously worked to have parental involvement. Since we are not a community school, and since the parents of our students speak a range of primary languages, it has been a slow process. A major concern of parents is that their students be in honors classes if they are to bother commuting the long hours, in some

cases three to five hours per day, to Bravo. This concern has been eliminated at the ninth-grade level in science because, as of 1999, we no longer offer any ninth-grade honors classes. We now offer only heterogeneous integrated science. It is interesting to note that this was instigated at the request of the current ninth-grade honors biology teachers who felt ninth grade was too early to delineate students who came from dozens of different middle schools with wide academic backgrounds. Although LAUSD insists that tracking is not done in the public schools, I feel that the current system, which allows schools to test students for diagnostic purposes, is often used to unofficially track students into honors sections of otherwise regular classes. With a rigorous academic curriculum in Integrated I and II, students will still be able to take and succeed in our AP courses without a prerequisite first year in that science. We anticipate that this approach, not usual in LAUSD, will satisfy concerns that parents have for their students.

Administration

As long as the teachers do the work necessary to get a majority vote, our principal is very supportive of integrated science. Likewise, all district science supervisors and advisors are supportive. Although no one will actually say that a school must go with an integrated approach, it is highly recommended as the only way to meet the State Science Content Standards for all students and the only way to prepare for the District/State Stanford 9 grade-level tests. Staff development monies are made available for team planning, and time is generously allocated for attending outside training sessions. Next year, our principal will, for the first time, make monthly department meetings a mandatory after-school event. Although this has always been allowed in our contract, it has never before been implemented at our school. In addition, science chairs will be expected to take a more directional role and will, for the first time, be compensated for their time. I will be department chair for next year, and I plan to make every effort to succeed with integrated science.

School Board

For five years, LA-SI has been a very well-funded grassroots project, which has allowed many schools to begin integrated science programs. Now, the district has taken over the administration of the project to a greater degree, and it remains to be seen exactly what level of support will be available for local school sites and individual teachers. I benefited greatly from the workshops, the opportunity to get additional credentials, expert advice, and camaraderie. Our school board recently added several new members. Our superintendent is very supportive of standards-based instruction, so we may see a continuation of support for integrated science as the best route to

implementing standards. LA-SI is compiling data related to an evaluation of the integrated science programs in many of the district schools to present to the school board. Once the school board has had a chance to review the LA-SI findings, LA-SI will release the findings to the public.

Colleges

Even though fewer than 20 percent of our students apply to the University of California (UC) or comparable universities, meeting the UC entrance requirements symbolizes the only path to college at our school. Therefore, it is great that, due to the diligent efforts of LA-SI, Integrated Science I, II, and III are right there on the UC application list and are given equal status with traditional biology, chemistry, and physics. Our program has not

Due to the diligent efforts of LA-SI, Integrated Science I, II, and III are right there on the UC application list and are given equal status with traditional biology, chemistry, and physics.

existed long enough to have any figures about acceptance rates. I do note that when I applied for National Board Certification, integrated science was not an option for either portfolio work or as a category at the assessment center. I was, however, allowed to use my integrated classes to document my teaching practices. National Board staff called me to see which of the traditional science evaluators should evaluate my integrated entries.

Curriculum Materials for the IS Program

In May 1996, when our science department decided to implement an integrated science program, another teacher and I examined the available texts. We already had decided that, although the district gave us the option, we were not interested in developing our own curriculum. We knew that the new state standards might change anything we might do and that developing a program from scratch might make us very resistant to change if needed. In addition, we did not want to set the precedent at our school that every teacher could design an independent curriculum without following any specific guidelines. Some schools already have found themselves in just such dilemmas.

Instead, for a number of reasons, we selected the Grossmont series, which is published by a tiny Southern California school district. It was rich in basic concepts in chemistry, physics, biology, and earth science. It was truly integrated in such a way that the sciences overlapped just as they do in reality.

The study of water in the first semester revolved around a scenario in which a town discovers its drinking water is contaminated and the students' task is to discover the culprit. Along the way, they are engaged in chemical tests of all kinds, biological analyses of several organisms, investigations involving filtration systems of both the earth and the kidneys, and engineering dilemmas involving how the speed at which the water flows over the town dam is affecting the oxygen content of the water. During the second semester, students investigate several aspects related to the atmosphere.

We always can use more time and resources for this endeavor . . .

In the second semester, a study of the electromagnetic spectrum introduces the study of photosynthesis, which leads to a study of the greenhouse effect. This study is entwined with both thermodynamics and a study of breathing problems, which leads to cellular respiration, and so on. A particular challenge in teaching integrated is to balance breadth with depth. Because this curriculum material presents concepts throughout the year in a spiral approach, students have several opportunities to master concepts in different contexts.

Since 1985, California teachers have generally obtained teaching credentials in either the physical or the biological sciences. Integrated teachers are often amazed initially to see the large number of concepts that are basic to all the sciences. For this reason, a student gets much more than the equivalent of just one semester of biology, chemistry, physics, and earth science in the two-year integrated sequence. The Grossmont text leaves a lot of room for local application to Los Angeles water and atmospheric conditions. It has room for teacher creativity and follows the inquiry-based approach. Furthermore, we thought it would be easy to make adjustments to it if needed when the new state standards were approved.

Unfortunately, the second year was not available when we needed it, so with apprehension, we ordered a different series (*Prime Science*, UC Berkeley, Kendall/Hunt Publishing) for Integrated II. Actually, for our site, it turned out best because had we been able to continue with the Grossmont series for Integrated II, its emphasis on physiology would have duplicated what our Integrated III will do. Integrated III will use our current physiology text supplemented with teacher-developed materials to include concepts from physics, earth science, chemistry, and biology. The teacher is an ophthalmologist with credentials in chemistry and biology.

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Teachers are greatly encouraged to supplement these curriculum materials, and we are well aware that standards-based instruction encourages less reliance on texts than did traditional science. In order to assure that all teachers deal equally with *all* sciences and do not revert back to their own single specialty (behind closed doors), however, we are at present encouraging each other to cover everything in these two sets of curriculum materials. Since our State Content Standards came out in February 1999, we have worked diligently to add or delete material to our basic program so that it will be in alignment. It has been very invigorating and slightly intimidating to the new teachers who will begin teaching integrated in September to hear the current teachers tossing around suggestions to add electrostatics to the weather unit or more redox to the photosynthesis/cellular respiration section.

We always can use more time and resources for this endeavor. Recently, each science room was upgraded to include six multimedia computers with rapid Internet access. We also have rapid access to each other through telephone and networked e-mail in each classroom.

Assessment

Assessment in our integrated classes is a mixture of alternative and traditional methods. While we encourage timed-practice testing using multiple choice format to interpret graphs and data to prepare students for the standardized state exams, we use a variety of other methods to assess student progress in course content. Written tests usually span an issue, such as global warming, that covers several interrelated concepts. Journal writing, peer evaluation, and portfolio work are encouraged. Oral presentations include debate, role play, and discussion. Students often engage in problem-solving activities that require them to design, implement, and collect data from labs to support their answers. Teachers have a variety of comfort and skill levels with respect to implementing these approaches to assessment. No one does only one kind.

See "How Do We Assess Learning in Integrated Science?" in Chapter 2 for ideas about assessment in integrated science courses.

Under the direction of our visionary principal and her insistence that we do what the district requires as far as discussing and planning for science reform, our school has kept current with California educational reform. We find that the integrated approach addresses the full scope of thematic, issues-oriented, inquiry-based science learning that is recommended for science literacy. We struggle constantly with the issue of English as a second or third

language and low math skills among most of our student body. Students perform at a variety of levels on these science assessments. At first, some rebel at having to think it out. Even more are indignant that their opinion does not necessarily get them many points. Gradually, they become more self-confident and more adept at looking for the science concept that is embedded in the question. Often, they learn as much from the assessment as they do from the preliminary studies. We stress rubrics and second chances. We do not have data on the current, and first, set of Golden State Exams that were administered to all our Integrated Science II students in May 1999. When we looked at paired studies for the State Stanford 9 test, we found the same range of improvement/regression for our integrated students as was exhibited by students in nonintegrated classes. LA-SI is developing grade-level exams for integrated courses within the school district, but formal evaluation is not available at this point.

Often, the students learn as much from the assessment as they do from the preliminary studies.

Plans for the Future

Because we already have made the decision to go with a full integrated approach, we have a ready list of future plans:

- make Integrated I and II so rigorous that students may go directly into AP Biology, AP Chemistry, or AP Physics successfully. We are talking about enrichment projects and perhaps an independent study "workbook" format that will provide additional mathematics rigor.
- secure pay for weekly after-school planning and debriefing sessions for teachers of integrated science. We hope this increases team trust so that no one fears "asking a dumb question" about someone else's specialty.
- increase cooperative use of resources and facilities and also work out an equitable system for sharing and replacing equipment.
- work with a testing coordinator to get as many standardized testing opportunities as possible.
- work with the newly hired Achievement Council to collect and analyze assessment data in a systematic way. Due to low achievement as measured by national testing, college entrance, SAT scores, and absentee and dropout rates, every high school in Los Angeles has had to submit to the superintendent a three-year plan by which the school intends to improve student achievement. As part of our plan, we are required to hire the independent educational advisory group, the Achievement Council, to assist us in implementing our plan. Our plan includes two major components that will benefit our integrated program. First, all teachers must

implement collaborative work among students in every classroom. Second, more students will be encouraged to take and be coached to succeed in AP classes.

- address the political and personal issues of teachers who are opposed to teaching integrated science.
- watch for ways to relieve stress and provide encouragement for department members new to all of this science reform.
- implement at least eight miniworkshops to be held during our mandatory monthly science department meetings. Topics will include inquiry-based learning, math in the science classroom, collaborative group work, assessing student work, and motivating students to engage in active learning.
- develop a two-year exit project for Integrated I and II since all students will be engaged in the same science classes and curriculum. The California Golden State Exam and a science fair project each year will be part of this project. We are considering an exit portfolio, which may include exhibitions such as video, multimedia, and models.
- take time to smell the roses.

See "Evaluating Progress and Sustaining the Change" in Chapter 3 for ideas.

Marilyn Perron has been teaching in Los Angeles city schools for seventeen years. She is National Board Certified in Adolescent and Young Adult Science. She has California teaching credentials in biology, physics, agriculture, psychology, sociology, and English literature. She holds bachelor's degrees in agronomy and in behavioral sciences and a master's degree in education. Prior to teaching, she owned a business management company in Orange County, California.

UTAH SCENARIO: THE INTEGRATED SCIENCE PROGRAM AT BEN LOMOND HIGH SCHOOL

BY

SUE FAIBISCH

DESCRIPTION OF SCHOOL

Ben Lomond High School is an inner-city, urban school located in Ogden, Utah. The school has a population of approximately 1,500 students. Ninth through twelfth grades are taught at Ben Lomond. The school is on a trimester system with a freshman center that involves the teaming of science, English, and geography teachers. Each set of three teachers makes up a family. There are three families in the freshman center. All freshmen are included in one of the three families. For the core classes of science, geography, and English, the students spend the entire year with the same teachers and family.

Ben Lomond is a diverse school district. About 25 percent of the student population is Mexican/Mexican American, 5 percent African American, fewer than 3 percent Native American and Pacific Islander, and the remaining percentage is Caucasian. It is enjoyable teaching in a school that has this cultural diversity. There are also plenty of difficulties teaching in this type of urban setting. Income levels are low to middle range, and many of our stu-

dents come from single parent homes or reside with other relatives. There are definitely those students who see no use for being in school when they could be working and making money.

In the four years I have been at this school, I have seen a definite increase in laziness among students. It has gotten harder to motivate them, even with projects and hands-on activities. Frequently, students just want the answers to questions because they do not want to think about problem solving. There are also those students who are highly motivated and help to pull the class out of its slump.

Because of a lack of funding, teachers often have to find external sources of money to fund projects and field trips. These aspects of teaching make the experience worthwhile for me, and I have actively pursued other funding to provide my students with experiences outside the classroom. It has helped to have a very supportive administration and board of education.

The science department has six full-time teachers, three of whom are in the freshman center. Core science courses that are taught throughout the school are Earth Systems, biology, chemistry, physics, human biology, anatomy and physiology, principles of technology, Advanced Placement (AP) Chemistry, and, when there is high enough enrollment, AP Physics. All the ninth graders at Ben Lomond are required to take freshman science, which is Earth Systems—an integrated science course. After the freshman year, students may take any other science courses that they wish.

As of 1999, science requirements for graduation are two credit hours of core science. This is in alignment with the state standard for high school graduation. Also in alignment with the state requirements, students need to choose one class from two of the four science categories listed below. The following courses are acceptable core courses according to state standards:

EARTH SYSTEMS Earth Systems* AP Environmental Science *grade nine, required	**BIOLOGY** Biology Human Biology AP Biology Agricultural Biology
CHEMISTRY Chemistry AP Chemistry	**PHYSICS** Physics AP Physics Principles of Technology

At this time, standardized assessment in science classes is the end-of-level exam given by the state. These exams are entirely multiple choice. The teacher guidelines that come with the test specifically state that these tests are not designed to be the only tool for assigning students a grade for a class.

Earth Systems is the ninth-grade integrated science course. The 1998–1999 school year is the first year that this course has been taught to Ben Lomond ninth graders.

They are to be used in conjunction with other assessments that the individual teacher creates. Within science classes, teachers choose to assess their students in a variety of ways: testing (multiple choice, essay, short answer, true/false, and practical application), group projects, presentations, written research papers, and other individual methods. This formula will change in our district in the upcoming years. During the spring of 1998, the Ogden City School District created a strategic plan that involves redesigning the curriculum. Strategy Four of this strategic plan reads, "To develop a district-wide curriculum design-and-delivery system to ensure all students achieve the strategic objectives." As part of this strategy, each field of study will have specific competency-based performance standards called anchor tasks. Students will be required to pass them before moving on. Each teacher will develop performance tasks, which will be any major assignment a teacher chooses.

Description of the Integrated Science Program

Earth Systems is the ninth-grade integrated science course. The 1998–1999 school year is the first year that this course has been taught to Ben Lomond ninth graders. There are three ninth-grade science teachers who each teach five sections of Earth Systems. This is the only science class that is required of all Ben Lomond students. There are approximately 450 ninth-grade students. There were twelve sections of Earth Systems being taught to upper-class students (ten through twelve) during the 1998–1999 school year. During the 1997–1998 school year, there were ten sections of Earth Systems taught to upper-class students. This course is specifically designed for the cognitive level of ninth graders, and therefore will no longer be taught at any other grade level after this year. Those students who fail Earth Systems in the ninth grade are required to make up the credit during night school or summer school.

In the Utah science core curriculum, ninth-grade integrated science focuses on the theme of "earth systems." When the scenario was written, the Utah State Office of Education required Earth Systems to be taught to all ninth

grades in the state. Recently this mandate was removed, although the core concepts remain the same. The Ogden City School District still requires Earth Systems for all ninth graders. Earth, physical, space, and life science content are integrated in a curriculum with two primary goals:

- Students will value and use science as a process of obtaining knowledge based on observable evidence.
- Students will develop an understanding of interactions and interdependence within and between earth systems and changes in earth systems over time.

See "Why Bother?" in Chapter 1 for a discussion of a rationale for integrated science.

Special emphasis in the core curriculum is given to the effects of biological processes on earth systems. Three major concepts underlying the operation of earth systems may be summarized as matter cycles, energy flows, and life webs. The web of life is intertwined with earth's energy flow and cycles of matter. Emphasis should be placed on the interconnections among earth's systems and on understanding how alterations in one part may affect the system as a whole.

The core was designed using *Benchmarks for Science Literacy* (AAAS, 1993) as a guide to determine appropriate content and process skills. Core concepts in science as well as skills from other curriculum areas should be taught using integrated approaches. Technology issues and the nature of science are infused into the core. Personal relevance of science is an important part of this core, and teachers are encouraged to emphasize this. It is our goal that a student's understanding of science should enable him or her to make informed and responsible decisions.

The core was designed using Benchmarks for Science Literacy *(AAAS, 1993) as a guide to determine appropriate content and process skills.*

The goals stated in the Intended Learning Outcomes should guide instruction. Hands-on, student-centered approaches to instruction with the student as scientist should be emphasized. Students gain enhanced understanding of concepts and processes by "doing" science. Instruction should extend beyond the core to meet student needs. The content and processes in this core articulate with the rest of the science K–12 core curriculum.

At Ben Lomond, the three Earth Systems teachers try to implement lessons in which the students are interested and that affect their lives directly. The core has been used as a skeleton guideline for covering specific themes. Each

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teacher adds flare to the core by incorporating activities, based on his or her own interest, that tie the core requirements together. At Ben Lomond, the ninth-grade students in science class are always actively participating.

The following are the standards and objectives that are required in the Earth Systems course:

Standard 3600-001:	Students will investigate biological systems and summarize relationships between systems.
Objectives	
01	Analyze the functioning of a biological system.
02	Determine how systems relate within the biosphere.
03	Analyze the carbon cycle.
04	Evaluate the influence of people on the biosphere.
Standard 3600-02:	Students will analyze the relationship between the sun's energy, the atmosphere, and earth.
Objectives	
01	Analyze the influence of the sun's energy on the atmosphere.
02	Using appropriate technology, analyze local atmospheric systems.
03	Determine the limitations of science and technology in predicting and controlling the weather.
Standard 3600-03:	Students will analyze the relationships between the atmosphere and biological systems.
Objectives	
01	Determine the consequences of atmospheric alteration to biological systems.
02	Predict and illustrate future physical and biological changes on earth based on current atmospheric trends.

Standard 3600-04:	Students will determine the importance of water to earth systems.
Objectives	
01	Relate the properties of water to earth systems.
02	Relate the importance of water resources to earth systems (for example, life processes, geologic processes, and others such as recreation and aesthetics).
03	Analyze the physical and biological dynamics of the oceans.
Standard 3600-05:	Students will analyze earth's geologic processes.
Objectives	
01	Summarize the systemic movement of earth's crust over geologic time.
02	Examine the effects of geologic processes on the surface of earth.
03	Distinguish between theory, law, evidence, fact, and superstition.
Standard 3600-06:	Students will analyze relationships between earth's crust and other earth systems.
Objectives	
01	Analyze how geologic processes affect other earth systems.
02	Relate global and local geologic resources to the biosphere.
Standard 3600-07:	Students will understand the flow of energy into and out of earth's systems.
Objectives	
01	Compare and contrast internal and external sources of energy.
02	Analyze the transfer of energy within earth systems.
Standard 3600-08:	Students will investigate the universe and earth's place in that system.
Objectives	
01	Research and describe scientific theories on the origin and structure of the universe.
02	Relate cycles of the earth, moon, and sun to earth systems.
03	Evaluate space exploration.

Attachment: Utah Scenario at the end of this scenario is a table showing the scope and sequence for the three integrated science courses in Utah. As of now, there is not enough communication between the seventh-, eighth-, and ninth-grade science teachers for this table to be accurate in the Ogden City School District. With two feeder middle schools to Ben Lomond, some students are coming into ninth-grade science having done requirements that are meant for the ninth-grade course and some are not. This has posed a great challenge in creating this new course at the ninth-grade level.

Background of the IS Program

Every ten years, the state science core undergoes a revision. Based on research discussed in *Benchmarks* suggesting that biology is not age appropriate for ninth graders, and because students also were not receiving any foundation on which to base higher-level science, the State Office of Education science coordinator decided to get a group of teachers together to create the integrated science program. The Utah State Office of Education held meetings around the state and invited all science teachers to give input on what to do about this situation. Eight to ten teachers rewrote the science core to include Earth Systems. The intent of this course is to (1) create a foundation of basic science process skills and concepts that students could use in higher-level science courses and (2) create a course that looked at science as a whole, not as isolated disciplines.

See Chapter 3 for a discussion of decision making and planning.

The course was field tested for one year. After the year, teachers who participated in the field testing came together to give feedback on the course. The development of this course was a two-year process, and the end result was based on both national research and teacher input. In 1995, the new core was published. Schools were given three years to implement the Earth Systems course before the State Office of Education began requiring the end-of-level exam. This was to allow schools the time to certify teachers in integrated science and to prepare materials to teach the new curriculum.

None of the current Ben Lomond teachers chose to be involved in the decision-making process, so when the final core curriculum was released, some Ben Lomond teachers were unprepared to implement the curriculum. Once the decision was made to incorporate Earth Systems into Ben Lomond, the administration and the district financially supported those teachers who pursued the integrated science endorsement. For supplies and materials to teach this new course, teachers had to rely on the $200 given to each teacher from the science budget at the beginning of the year along with

any lab fees ($5 per year per student) that were collected. Because our school is an urban school, there are many low-income families that fall under fee waiver. This has posed some difficulty for science teachers in purchasing supplies and equipment necessary to adequately teach any science.

For two years, there has been no text to accompany the Earth Systems course. For the 1999–2000 and 2000–2001 school years, the science department has allotted its annual $5,000 book fund to buy books for Earth Systems. Because this integrated course is very hands-on, having no text has not mattered much. Teachers have to be more creative with their approach to lessons, but a text would have been useful to the students for research and background information. During the spring of 1998, our department wrote three small grants, which our district approved. Together, these grants increased the Earth Systems budget for materials and equipment to about $3,200. During the 1998–1999 school year, a retired science teacher who is on the Ogden School Foundations Board made a push for our science department to receive an additional $5,000 from the foundation to help purchase additional materials. The school district agreed to provide a matching $5,000, although there were stipulations on how we spent this money. This unexpected $10,000 helped our science department purchase supplies and equipment to teach Earth Systems as well as the other science courses; textbook purchases would fall into a different category.

The three science teachers in the freshman center are teaching Earth Systems. Before Earth Systems was implemented into the freshman center, freshmen took biology. All three teachers were endorsed in biology. At the time of the change, one ninth-grade teacher switched with an upper-level teacher who was endorsed in integrated science. Of the remaining two freshman science teachers, one now has the integrated science endorsement and the other is considering finding a new job.

Concerns of the Stakeholders

Teachers

In 1995, two of the three ninth-grade teachers and the principal at Ben Lomond did not agree with the state science coordinator's decision to implement an integrated science program in the ninth grade. Biology was the class being taught, and two of the three teachers were adamant about continuing to teach biology. A meeting was held with the secondary science teachers from the two high schools in the district, both high school principals, district science personnel, and the state science coordinator.

See Chapter 3 for a detailed look at the concerns of stakeholders.

This meeting was put together by a former Ben Lomond science teacher, who was one of the original developers of the new core, and the ninth-grade principal. The purpose of the meeting was to discuss implementing Earth Systems into the ninth grade at our school. The discussion was heated. Because the state science coordinator made a statement that implied implementing this course was optional, the principal of Ben Lomond decided that we would continue to teach biology in the freshman center.

During the 1996–1997 school year, the state science coordinator informed Ben Lomond administration that indeed, we were required to teach Earth Systems. The administration decided, after some teacher input, that our school would teach Earth Systems to tenth- through twelfth-grade students who needed another science credit to meet graduation requirements. In the year 1997–1998, upper-class students filled ten sections of Earth Systems. Later the same year, the State Office of Education informed our administration that the Earth Systems course was designed for the cognitive level of ninth-grade students only, and it was inappropriate for the course to be taught to upper-level students. As a result, during the 1998–1999 school year, Earth Systems was implemented in the freshman center. Because of prior registration, however, we offered twelve sections of Earth Systems to upper-class students for the last time. The upper-level teachers who have been teaching Earth Systems for the past two years are glad to have more sections of traditional science courses. While we were offering Earth Systems to the upper-class students, the enrollment in all other science courses dropped. Now, however, registration for the 1999–2000 school year shows there is a definite increase in enrollment for biology, chemistry, and physics. Of the three teachers teaching Earth Systems in the freshman center, two are content with continuing to teach the course; the one teacher who was not pleased with the change from the beginning plans to become a guidance counselor.

Students and Parents

The freshman center has existed for four years. Although the majority of the freshmen are content, every year some students complain about being required to be in the freshman center. These students would like to be allowed to take classes like the upper-class students. Generally, parents like the student in the same class with the same teacher for the entire year. From my experience teaching Earth Systems to the freshmen for the first time, it seems that the students like the hands-on aspect of this course. At the beginning of the 1998–1999 school year, only one student and his parent complained that the course was too easy for him.

During our parent night for the freshman center, about one-third of the parents and students participate; the same holds true for the two parent-teacher conferences during the year. Of those parents, none have had complaints about the science course. In fact, parents have made comments that their child likes "doing" things during science. According to ninth-grade science teachers and school guidance counselors, no parents have made comments one way or the other about the change in curriculum for the ninth-grade science core.

Now that the curriculum has changed, the administration has been very supportive and has allowed the teachers to "do what is good for kids" (Ogden City School District superintendent) with respect to the integrated science course. District personnel have been fairly hands off with respect to how the teachers are teaching Earth Systems. By matching a $5,000 grant during the 1998–1999 school year, the district demonstrated its financial support of the program.

Because the freshman center is the ideal teaching scenario, the science teachers have ample opportunity to team teach with the geography and English teachers. Teachers' schedules are flexible enough in the family setting that whenever more time is needed for certain activities, the team teachers easily adjust their family schedule without needing to seek permission from the administration.

Administration

The district science coordinator has been helpful in finding professional development opportunities. Because Ben Lomond was given Centennial School status in 1995, there has been extra money to plan course work and to provide opportunities for teachers to attend professional development courses. Unfortunately, after the 1998–1999 school year, there will be no more money available from this source. The district will allow one paid substitute per teacher for a professional development course per school year. The science teachers, however, may request further funding through the Eisenhower funds the district receives.

School Board

The school board did not play a specific role in implementing integrated science in Ben Lomond High School. Because the integrated science curriculum allows for many creative project ideas, students, however, have developed projects in which they have needed permission from the school board. All experiences I have had with the school board with respect to Earth Systems projects have been overwhelmingly supportive. All of the board

members buy into the district's mission statement that "If it's good for kids [educational experiences], then why not try it."

Colleges

According to the Utah State Office of Education, Earth Systems is a course that is accepted by colleges and universities. Earth Systems is considered a core science class and not an elective. From data our district collects each year on seniors going on to higher education, approximately 20 percent go on to two-year schools and 35 percent go on to four-year schools. These percentages include all educational training beyond high school such as vocational and university. Because integrated science is so new in our school, only a small percentage of seniors this year have taken Earth Systems. It will be another four years before the present freshmen graduate from Ben Lomond and move on to other educational experiences.

Curriculum Materials for the IS Program

Each teacher has a copy of the state core curriculum for secondary science courses. It is up to the individual teacher to decide how to teach the core standards and objectives. This allows for a lot of creativity based on an individual teacher's talents. At Ben Lomond, the three ninth-grade science teachers share ideas and talk about where they are in the curriculum, but they do not teach identical activities or lectures. Because teachers share ideas, there is some overlap in activities, but for the most part, the core is taught in different ways.

Since Earth Systems has been taught at Ben Lomond, there have been no textbooks. The district and the school have not allotted any extra money for the purchase of textbooks. At the end of the 1998–1999 school year, the three teachers liked teaching without a textbook, although for students who missed a lot of class time, a text could have been beneficial in helping them catch up on material. Without a text, teachers use a wide variety of other resources to cover core material. For example, teachers use readings from current newspapers and journals to practice reading skills and to tie Earth Systems to the real world. Recently, the science department cochairs, both of whom are Earth Systems teachers, have been investigating what text to use to enhance the Earth Systems course. They have decided that within the next two years a combined series of Prentice Hall *Science Explorer* books will be purchased.

I have enjoyed creating my own curriculum, although it has been exceptionally time consuming. Even though we may be purchasing textbooks soon, I

will continue to use the ideas developed this year and perfect them. Time has been the most limiting factor in developing curriculum. Now that the first year of development is finished, the upcoming years will allow for refinement.

Assessment

Throughout the year, students are assessed on their progress through the use of tests and quizzes as well as group and individual projects. From my experience teaching biology and Earth Systems, there is no difference in assessment techniques for the integrated science and the discipline-specific course. We use a combination of strategies such as research projects, experimental design and implementation, presentations, short answers, essays, and practical tests. At the end of the course, there is a state end-of-level exam that all Earth Systems students take. Because the freshman center teachers believe cross-discipline instruction is important, there is definite interdisciplinary assessment by all three family teachers (English, geography, and Earth Systems). Because this type of assessment is new to the students, it takes some adjusting to on their part, but overall, those students who put forth at least some effort do better in all three core classes. Those students who do not participate in these interdisciplinary assignments do worse in all three core classes.

See "How Do We Assess Learning in Integrated Science?" in Chapter 2.

Because this was the first year Earth Systems was taught in the freshman center, as one might expect, the results on the state end-of-level exam were fairly low. The following are the percentage grades of 301 students based on an A–F grade scale: 8 percent - A, 18 percent - B, 25 percent - C, 15 percent - D, and 35 percent - F.

Plans for the Future

There are no current plans to expand integrated science in our school or district, other than to refine the teaching of our seventh-, eighth-, and ninth-grade science state core curriculum. At the present time, there is not adequate communication among these three grades to have any real articulation between them. Because all three years are integrated science, there needs to be some communication between the science teachers of all three grades. As a ninth-grade teacher, I know that there have been numerous occasions when there has been too much overlap between what students did in seventh and eighth grade and what they are supposed to do in ninth grade. There also is the problem that the two middle schools that feed into Ben

Lomond High School do not communicate with each other. When the students from these two schools meet in our classes, there is always a tremendous amount of discrepancy in their past experience with science and in their current knowledge. In four years, I have not been aware of any time when the two middle schools and the high school science teachers met to discuss the scope and sequence for the integrated science classes. I believe this is the direction in which our district must move to adequately teach the three years of integrated science.

As previously stated, Earth Systems was implemented at Ben Lomond for upper-class students who had failed biology and needed science credit to graduate. According to the guidance counselors, none of the students who has taken Earth Systems as a back-up science class is college bound. Now that Earth Systems is required for all ninth-grade students, there will be some who pursue a college degree.

A separate comparison was made among the classes of one ninth-grade teacher who taught ninth-grade classes of Earth Systems and one section of upper-class Earth Systems. Of 125 ninth-grade students, the grades were: 0 percent - A, 9 percent - B, 21 percent - C, 18 percent - D, 52 percent - F. Of twenty upper-class students, 0 percent - A, 5 percent - B, 15 percent - C, 20 percent - D, 60 percent - F. According to the school's guidance counselors, these students are poor attendees, not college bound, and are struggling to make the minimum requirements in science for graduation. This is the first year for giving this end-of-level exam, so there are no previous scores with which to compare these. Without having the previous three years' biology test scores, it is hard to make a comparison between the two different science classes for ninth-grade students.

Other Characteristics of the IS Program or Experience

Because this is the first year of integrated science in Ben Lomond's freshman center, teachers are working on making the course a truly integrated/interdisciplinary science course. One such example is a culture project in which students write a research paper on a culture of their choice and then, with a team of students, design their own culture. All three science teachers have teamed with their fellow English and geography teachers to develop interdisciplinary assignments. Some of these assignments are one-day activities, others are trimester-long projects. All the freshman center teachers help to make the interdisciplinary aspect of education work. The science teachers have made sure to include field study projects that get the students out of

the classroom and into the environment the students are studying. For the upcoming school years, the teachers will be working on fine tuning these projects as well as developing more real science opportunities.

Before moving to classroom teaching, Sue Faibisch was an environmental educator in New York, Massachusetts, and California. She has taught ninth-grade science at Ben Lomond High School since 1995. For the past two years, she has been a science department cochair. Her bachelor's degree is in biology as is her master of arts in teaching (MAT) degree. She has written numerous grants to enhance her science teaching and is a firm believer in project-based learning. She has received two teaching awards in the past two years: the Focus on Excellence Award given by the Ogden City Board of Education, and the Water Educator of the Year Award given by the Utah State Division of Water Resources. She has been involved as a presenter/instructor for the Weber State University/Utah State Office of Education First Year Science Teacher's Workshop and as a facilitator for Project WET (Water Education for Teachers).

ATTACHMENT: UTAH SCENARIO

SCOPE AND SEQUENCE OF TOPICS/STANDARDS SEVENTH- AND EIGHTH-GRADE INTEGRATED SCIENCE AND NINTH-GRADE EARTH SYSTEMS

Science Domain		Grade Seventh	Eighth	Nint
Energy Magnets, heat, light, electricity, sound, work, and machines				
3240-03	Students will relate forces and energy to motion.		X	
3240-04	Students will construct various machines and compare the work done by them.		X	
3600-07	Students will understand the flow of energy into and out of earth systems.			X
Chemistry Air, water, matter, weather, soil, rocks and minerals				
3200-01	Students will evaluate the particulate nature of matter.	X		
3240-01	Students will observe and describe chemical and physical change.*		X	
3240-05	Students will investigate changes in earth's crust and climate.*			X
3600-04	Students will determine the importance of water to earth systems.			X
Living Things Animals, plants, microorganisms, ecology				
3200-03	Students will understand structure and function of cells and organisms.	X		
3200-04	Students will understand reproduction and heredity of organisms.	X		

* Indicates this Core standard is cross-listed in another science domain.

(continued)		Seventh	Eighth	Ninth
Living Things Animals, plants, microorganisms, ecology				
3200-05	Students will create, use, and understand the application of classification schemes.		X	
3600-01	Students will investigate biological systems and summarize relationships between systems.*			X
3240-02	Students will investigate changes in biological energy.*		X	
Physical Earth Geological features, natural resources				
3200-02	Students will compare and contrast the structure of earth's crust and interior.	X		
3240-01	Students will observe and describe chemical and physical change.*		X	
3240-02	Students will investigate changes in biological energy.*		X	
3240-05	Students will investigate changes in earth's crust and climate.*			X
3600-03	Students will analyze the relationship between the atmosphere and biological systems.			X
3600-05	Students will analyze earth's geologic processes.			X
3600-06	Students will analyze relationships between earth's crust and other earth systems.			X
Space Earth-sun-moon relationships, solar system, universe				
3600-02	Students will analyze the relationship between the sun's energy, the atmosphere, and earth.			X
3600-03	Students will analyze the relationship between the atmosphere and biological systems.*			X
3600-08	Students will investigate the universe and earth's place in that system.			X

FLORIDA SCENARIO: INTEGRATED SCIENCE IN BREVARD PUBLIC SCHOOL DISTRICT

BY
GINGER DAVIS AND RAUL MONTES

DESCRIPTION OF SCHOOL

BREVARD PUBLIC SCHOOLS

Brevard County, in East Central Florida, is called "The Space Coast" because it is home to both the Kennedy Space Center and miles of wide Atlantic coast beaches. Port Canaveral, Indian River Lagoon, Florida Institute of Technology, Harris Corporation Headquarters, and Ron Jon Surf Shop are also significant to the diverse economy and lifestyles of Brevard. The Brevard Public School District is the forty-seventh largest district in the nation and the ninth largest in Florida. It serves 70,000 students in ninety-seven schools. Thirty-four percent of our students live in low-income households. Seventy-nine percent of our students are Caucasian, 14 percent are African American, 4 percent are Hispanic, 2 percent are Asian, and 1 percent are from other racial and ethnic groups. Fifteen percent of our student population has been identified as "disabled," 7 percent as "gifted."

Science in Brevard

The Brevard Public School District has defined an articulated PreK–12 science sequence. Brevard's *Science Spiral Progression* identifies core science concepts and skills at each grade level, which are aligned with state and national standards. This work has been widely shared with and used by schools across the nation. Three science credits are required to graduate from Brevard's high schools. Any three science credits once fulfilled this requirement, but beginning with the graduating class of 2000, students *must* complete the three-year integrated science sequence *or* biology, chemistry, and physics in order to graduate. Both sequences are offered at regular and honors levels. Students are encouraged to also take a fourth year of science, and have many courses from which to choose, including Advanced Placement (AP) science courses, anatomy and physiology, marine science, and Integrated Science IV. Brevard also boasts a successful Science Research Program, offered at each secondary school for elective credit, in which students work under the direction of a science teacher on original scientific research.

Description of the Integrated Science Program

One hundred percent of students in grades PreK–8 participate in an integrated science curriculum as outlined in our *Spiral Progression*. At the elementary school level, it is simply called "Science," and at the middle school level the courses are called "Comprehensive Science" to be consistent with state course titles. In grades nine through twelve, students have the option of continuing in the *Spiral Progression* by taking Integrated Science I, II, and III, or of taking biology, chemistry, and physics. As of January 1999, 55 percent of students were enrolled in the core integrated sequence (20 percent in honors, 80 percent in regular), and 45 percent were enrolled in the traditional core courses (55 percent in honors, 45 percent in regular).

Each integrated science course addresses standards across eight strands of science, which are coordinated around a unifying theme: The Nature of Matter; Energy; Force and Motion; Processes That Shape the Earth; Earth in Space; Processes of Life; How Living Things Interact with Their Environment; and The Nature of Science. Attachment: Florida Scenario at the end of this scenario provides more detail about these strands. There is an emphasis on developing concepts, connections, and thinking skills while guiding students to learn at successively higher levels of abstraction each year. Instructional strategies are designed to actively engage students and to accommodate diverse learning styles. The standards and topics for the honors and regular courses are similar, and both levels are designed to be relevant and challenging. The

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primary difference lies in the level at which students are required to function. Honors classes put more focus on analysis, synthesis, and evaluation skills. Regular classes spend more time on comprehension and application.

Background of the IS Program

In 1993, concerned educators in Brevard identified improved scientific literacy for *all* students as a priority issue. Areas of concern included inability of students to apply scientific concepts to real-world situations, large numbers of students graduating without chemistry or physics knowledge, underrepresentation of minorities in high-level courses, and a common perception among students that science was boring and irrelevant. In light of the mounting evidence that scientific literacy is essential in our technological society, the need for science reform seemed clear.

See Chapter 3 for details about planning and decision making.

Brevard's Science Leadership Team, comprised of teachers representing a wide spectrum of experiences and philosophies, was established to research potential solutions. Efforts focused on studies in science education, national and international standards, and research in learning. Each team member was responsible for seeking input from administrators, parents, students, and fellow teachers throughout the process. The team was concerned with the K–12 curriculum and its articulation. This broad vision was important, but also contributed to the complexity of the task.

When the team first convened, there were still the questions Why integrated science? and Why change at all? Due to the diversity of the team, agreement about a range of issues, initially, was difficult to achieve. Team members had different definitions of integrated science and different philosophies about the content of integrated science. At the high school level, it was difficult to think about the traditional content in biology, chemistry, and physics in light of the state's new eight strands. It also was difficult to try to determine when during a three-year sequence certain topics should be covered. The team used both Project 2061's *Benchmarks* (AAAS, 1993) and NSTA's *Scope, Sequence, and Coordination* to make these decisions. The process was long and required extended dialogue.

Finally, the team endorsed the statement "Student Needs Are Our First Priority" as its guiding principle. From that point on, consensus on other issues was achieved more easily. After extensive study and discussion, the team reached consensus that it would recommend a high-level integrated science curriculum for all students in Brevard.

Professional Development

Professional development for science teachers is a high priority, and training opportunities have been extensive, especially for integrated science teachers. The training needs of all secondary science teachers were assessed, and opportunities were provided to assure that every need was addressed. Topics included research in learning, laboratory techniques, best practices, science in the workplace, science in daily life, use of advanced technology, national education reform efforts, curriculum integration strategies, assessment, content updates, and current issues in science.

See "Supporting Change through Professional Development" in Chapter 2.

Some teachers, of course, struggled with the added requirements, so a range of incentives was established. One of the most helpful things the district did was to provide a wide range of delivery methods for these professional development opportunities. We hoped that if we offered enough diversity in access, we would be able to meet the preferences of a wide target group. We offered the following: after-school workshops; one-day workshops; one-, two-, and three-week institutes; graduate credit seminars at Florida Institute of Technology; a behind-the-scenes, two-week institute at NASA; full-day workshops at Harris Corporation Headquarters; and workshops at Florida Solar Energy Center, Brevard Zoo, U.S. Space Camp, and Astronaut Memorial Foundation.

For one full year, teachers were also invited to select and take college courses, at institutions of their choice, to update and enhance knowledge and skills. Tuition and books were paid for by grants the district received, and teachers who successfully completed all requirements were paid for their time. In addition, interested teachers were funded to participate in state and national science conferences and conventions. There has also been an emphasis on vertical communication among PreK–12 teachers of science within feeder systems (elementary, middle, and high schools serving the same students). Funding support has been provided to promote articulation, planning, problem solving, project development, and training within feeder systems, with a focus on addressing the *Science Spiral Progression* and the needs of students as they learn. This approach has been well received and productive.

It also is important to point out that the time line that the district developed for implementing integrated science was gradual enough so that teachers, administrators, and schools could prepare.

Time Line for Change

Fall 1993:	Science Leadership Team recommends integrated science.
Spring 1994:	Teacher workshops and graduate-level seminars begin.
Summer 1994:	Science Leadership Team produces *Scientific Literacy for All.*
Fall 1994:	Comprehensive (Integrated) Science begins in middle schools. Teacher training opportunities continue.
Winter 1994–1995:	Grant proposal submitted. Teacher training opportunities continue.
Spring 1995:	Notification of grant award to support reform efforts received. Teacher training opportunities continue. Graduate-level seminar offered. Paid college course opportunities begin. Paid teacher-planning/articulation opportunities begin.
Summer 1995:	Summer institute at NASA for Brevard teachers held. Teacher training opportunities continue. *Scientific Literacy for All* revised and expanded. *Integrated Science* curriculum guide produced.
Fall 1995:	Seven schools initiate early implementation of integrated science in grade nine. Formal training-needs assessment performed. Teacher training opportunities continue.
Winter 1995–1996:	Teacher training opportunities continue.
Spring 1996:	Science advisory council established. Graduate-level seminar offered. Teacher training opportunities continue.

Summer 1996:	Teacher training opportunities continue. Letters sent to colleges nationwide requesting acceptance of integrated science. *Integrated Science* curriculum guides expanded.
Fall 1996:	All district ninth-grade students have opportunity to enroll in integrated science (tenth grade for early starters). Teacher training opportunities continue.
Winter 1996–1997:	School board approves strengthened graduation requirements for science. Teacher training opportunities continue.
Spring 1997:	Teacher training opportunities continue.
Fall 1997:	Integrated science available to all ninth- and tenth-grade students (eleventh grade for early starters). Teacher training opportunities continue.
Winter 1997–Summer 1998:	Teacher training opportunities continue.
Fall 1998:	Integrated science available to all ninth-, tenth-, and eleventh-grade students (twelfth grade for early starters). Teacher training opportunities continue.
Winter 1998–1999:	Teacher training opportunities continue.
Spring 1999:	Early starters graduate in first integrated science class. Teacher training opportunities continue.
Summer 1999:	Teacher training opportunities continue.

Support

The greatest expense related to integrated science is professional development, which has been an investment from which many teachers and their students have benefited. Most of our professional development activities are supported with existing resources, primarily Title II funds. Workshops targeting integrated science teachers address topics, skills, and issues of interest to most science teachers, so that all of our science teachers have had opportunities to participate, learn, and grow. District funds were used for the development of curriculum documents, again within our existing funding structure. We received an $80,000 State Department of Energy grant, which gave us a nice funding boost and allowed us to increase opportunities for teachers, including paid teacher articulation time and college courses. Also, many of our local institutions committed their support to helping us accomplish our curriculum and instruction goals. (In most cases, this support involves services rather than dollars.) Among the agencies providing support are NASA, Harris Corporation, Florida Institute of Technology, University of Central Florida, Brevard Community College, Brevard Zoo, Florida Solar Energy Center, Brevard Museum of Art and Science, Canaveral Council of Technical Societies, Boeing Company, Department of Natural Resources, U.S. Space Camp, and University of Florida Cooperative Extension Service.

Concerns of the Stakeholders

Teachers

See Chapter 3 for details on concerns of stakeholders.

Brevard has approximately fifty teachers who teach integrated science at the high school level. Because the curriculum is challenging, our deputy superintendent for school operations requested that principals select their most highly skilled teachers to teach integrated science. In reality, teachers often select themselves. Integrated science tends to attract our young teachers and our more innovative teachers, while many of our older, more established teachers prefer the traditional curriculum. (This seems to be the pattern for most change efforts.)

Some of the more experienced teachers do not see the benefit of integrated science and still think that the district should not have made any changes. Other experienced teachers see the benefit of integrated science, but do not want to teach it themselves, either because they are not inclined toward change, or they do not feel competent enough to teach out-of-field and do not want to do the extra work required to become competent. In Brevard County, teaching assignments are based on teacher certification, course

offerings, and student selections. In some cases, there are teachers teaching integrated science who do not wish to do so, and in other cases there are teachers teaching traditional courses who do not wish to do so.

The more that teachers have taken advantage of the professional development opportunities available to them, the more they have embraced integrated science. Also, the longer a teacher teaches integrated science, the more he or she seems to enjoy it. Some of the integrated science program's biggest adversaries initially are now among its greatest advocates. The integrated science program has encouraged increased communication and teamwork within school science departments as well as throughout the district. The emphasis on problem solving, relevance, and active engagement of students has had a positive impact on both integrated science and traditional classrooms.

> The characteristics that I enjoy about teaching integrated science are flexibility and motivation that are inherent with this approach to science. Integrated science empowers intelligence, creativity, and originality, and I think that the combination is a definite plus for the students.
>
> John Latherow, Teacher, Cocoa High School

Students

Fifty-five percent of our high school students were enrolled in Integrated Science I, II, or III during the school year 1998–1999. Thirty-one percent of students in core honors science classes were enrolled in integrated science, which represents 20 percent of the total integrated science enrollment. Sixty-eight percent of students in regular core science classes were enrolled in integrated science, which represents 80 percent of the total integrated science enrollment. An even greater enrollment is projected for 1999–2000. Also, in the fall of 1999, at least three schools will have full classes of Integrated Science IV, which will exceed the three-credit requirement for graduation. Student response has been positive, especially in our stronger school programs. Student response also seems to be more enthusiastic the longer the student has been in the program. Additional information needs to be collected and analyzed, but it appears that now more students are enjoying science and that more students are choosing to take an optional fourth year of science than before integrated science was implemented. Also, district secondary science scores have gone up every year since our reform efforts were initiated. Nationally normed CTB Terra Nova tests, administered in spring 1999, show that 41 percent of our ninth-grade students scored in the upper quartile in science and that 71 percent of our students performed above the national average in science. This represents significant growth.

> Integrated science provides a means to show how all areas of science share a common relationship. By integrating areas of science, we are equipped with a powerful tool to face future challenges.
>
> Jay Michaels, Eleventh-Grade Student, Cocoa High School, 1999 International Science and Engineering Fair Winner

PARENTS

Initially, there were strong parent concerns about integrated science, particularly as it related to college admissions. These concerns were voiced in a range of ways—through phone calls, letters of concern, and open school board meetings. There were also strong supporters of integrated science, but the opponents were more vocal. A Science Advisory Council was formed in response to the parents' concerns. This advisory council was made up of parents, teachers, school district personnel, community educators, and business leaders. The school board, along with the assistance of the Science Advisory Council, held informational meetings and provided parents and students with documentation about the proposed integrated science courses as a way of addressing their concerns.

Due largely to the concerns expressed by parents, it was determined that both the integrated and the traditional sequence would be offered to all secondary students, rather than an integrated science sequence for all students as originally proposed by the Science Leadership Team. As positive responses were received from colleges and as parents learned more about integrated science, attitudes have become more positive. Many parents have expressed that these courses have stimulated an interest in science by their children that was not previously apparent. Other parents have been pleased with their children's success in learning challenging concepts. Parents who do not understand or support integrated science can and do encourage their children to enroll in the traditional sequence. Ultimately, it was parent support that encouraged our school board to approve implementation plans for integrated science.

> Integrated science provided my son with a challenging science education that met his needs. Not only did he gain knowledge, but learned to see, appreciate, and be thoughtful about the application of science all around him. My son was accepted to the college of his choice and also received a scholarship.
>
> Rochelle Cisneros, Parent

Administration

School and district-level administrators in the Brevard Public School District have been extremely supportive of district science reform efforts, including integrated science. Although change necessarily creates more burdens for the administrator, most have a strong understanding of the need for change and have put their full support behind these efforts. Both the deputy superintendent for school operations and the director of secondary programs are extremely knowledgeable and supportive of the integrated science program. The time, effort, and resources they have committed to integrated science have been significant to its success.

Specific principals may be less supportive of integrated science, and in these cases, students' options to take integrated science may be limited. In such cases, the integrated science classes may end up as remedial classes. The incentive to support integrated science is quite strong, however, and if a principal does not support the program, eventually there would be consequences such as loss of funding for implementing integrated science, loss of professional development resources such as in-services, and likely some loss of professional repute in the science community.

For the most part, principals have been strong supporters of this change. Several principals have supplied additional school-level resources to their teachers in support of integrated science, above and beyond the district-level resources provided.

> I have followed the evolution of integrated science at the high school level for the past several years. I have found that students benefit from the exposure to the many science disciplines. Teachers are able to offer varied lessons to students, which helps keep them involved, interested, and above all else, learning science.
>
> Robert Clay Hutchinson, Assistant Principal
> Cocoa High School

School Board

The school board of Brevard County is an elected body, with all the political concerns typical to elected officials. The composition of the board changes every two years, bringing new faces and opinions. In November 1994, the efforts and recommendations of the Science Leadership Team were publicly commended by a school board member. By November 1995, these same efforts were questioned by school board members. A major concern of the

board was the removal of the traditional track of biology, chemistry, and physics. The Science Advisory Council and district personnel clearly demonstrated to the board through a number of presentations and reports that there was a need for increasing science knowledge among all students and for requiring all students to take more science. In 1994–1995, only 32 percent of the district students were completing the traditional track. In January 1997, following many months of meetings and important dialogue, the school board approved strengthening our science graduation requirements by requiring students to earn their three science credits in a core sequence of either integrated science or biology, chemistry, and physics. The current school board has requested and receives quarterly reports on the success of integrated science.

> I want to express my sincere appreciation for the document *Scientific Literacy for All* that you produced last summer.... The exciting, creative, innovative, and motivating strategies you are introducing to Brevard students will truly prepare them for the twenty-first century.
>
> Dr. Patricia Manning, Retired,
> University of Central Florida,
> Former School Board Member

Science Advisory Council

The Brevard Science Advisory Council was established in 1996 to facilitate collaboration among local stakeholders who are committed to excellence in science education. This group comprises educators, parents, scientists, engineers, college faculty, and other community members. It helps identify resources within our community and provides input on the future of science education in Brevard. This group was instrumental in prompting the school board to strengthen graduation requirements in science. It also has helped to develop a Web page of resources for local science teachers, is reviewing grant possibilities for our science programs, and assists in identifying and providing learning opportunities for teachers and students. The open communication among the members of the Science Advisory Council has contributed to a greater understanding of integrated science within the community and has assisted us in our efforts to gain support for quality science education programs.

Colleges

Our district sent letters to colleges and universities across the nation explaining Brevard's integrated science courses and requesting approval. As of June

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1999, all responses have been supportive. Among the positive responders were Stanford University, Georgetown University, Yale University, and the U.S. Air Force Academy. The district office has received a few questions regarding scholarships and weighted grade-point averages, each of which has been resolved in favor of the student thus far. We also have received a call from a parent eager to enroll his daughter in integrated science because his recently graduated son was granted a year of college science credit as a result of his integrated science background. Because integrated science is still a relatively new course, we expect there will be a continued need to communicate with college admissions offices to assure that they recognize and understand the course titles and numbers.

> I applaud your efforts to improve science education. Let me assure you that your students will be at no disadvantage in competing for admission to Yale.
>
> Kenneth Andersen III, Science and Engineering Coordinator, Yale University

> We are pleased to consider applicants who have followed this course of study in the sciences.
>
> James Montoya, Dean of Admissions, Stanford University

Curriculum Materials for the IS Program

The integrated science curriculum is defined by standards and student performance objectives rather than by a textbook. Curriculum guides for each course have been developed by district task teams of local educators. Teacher teams at individual schools also have worked to produce their own additional instructional materials. Developing activities to meet the performance standards is very time intensive. The district developed suggested outlines as a tool for teachers, and regular in-services provide an opportunity for teachers to share successful activities and practices.

Brevard is fortunate to have the support of NASA and other local agencies in these efforts. Existing district- and school-level funds are used to support these activities. Students and teachers are encouraged to use a variety of high-quality resources and references including current books, periodicals, telecommunications, and multimedia technology. The effective use of current and varied resources provides a variety of perspectives, up-to-date

information, and an instructional focus on science concepts rather than textbook chapters.

Funds are allocated to purchase a district-adopted textbook for each student, and the parents were particularly insistent that the students have a textbook. A committee comprised of parents and educators selected *The Sciences: An Integrated Approach*, by James Trefil and Robert Hazen. Publishers John Wiley and Sons produced a specially bound issue for Brevard, which addresses some of our specific needs. The book is used as a resource rather than a curriculum. Sufficient time and funding to produce, expand, and revise curriculum materials continues to be a pressing need.

Assessment

See "How Do We Assess Learning in Integrated Science?" in Chapter 2.

Assessment of the integrated science program has proven to be a difficult issue because our district has traditionally tested only grades nine and below on nationally normed standardized tests. Results on these tests indicate significant growth at ninth grade, which may be attributed to our integrated approach. We have no such data for grades ten or eleven. On the spring 1999 CTB Terra Nova tests, 41 percent of Brevard's ninth-grade students scored in the upper quartile (compared with 30 percent in 1996), and only 8 percent scored in the lower quartile (compared with 19 percent in 1996). Ninth-grade students in 1999 scored ten percentile points higher than ninth-grade students in 1996, and twelve points higher than they scored two years ago as seventh graders. This movement of students from lower achievement to higher achievement may be evidence that our approach is working.

District-developed tests assess how our tenth- and eleventh-grade students are performing, but there has been no consensus among local educators on their validity. Our 1996 results were favorable to the integrated sequence, 1997 results were favorable to the traditional sequence, no test was developed in 1998, and results for 1999 have not yet been determined. Because testing is expensive and time consuming, our district has not made sufficient progress in this area. Purchasing a nationally normed test for eleventh-grade science is under consideration if resources will allow. This would provide information on how our students compare with national norms, but would not indicate growth or decline because there is no historical data. The existing ninth-grade data appear to make a case for the success of our curriculum efforts.

Plans for the Future

The Brevard Public School District hopes to improve and enhance its existing integrated science curriculum. Professional development and curriculum revision will be ongoing to assure the strongest possible programs. We will continue to share our materials and experiences with other school districts, and we welcome visitors to learn from our mistakes as well as our successes.

> To grow is to change, and to become perfect is to
> have changed many times.
>
> Cardinal Newman

Ginger Davis serves Brevard Public Schools as the district science resource teacher. Her twenty-four years of experience in education include working with students of all ages (prekindergarten through graduate school) and performing a multitude of jobs (classroom teacher, adjunct professor, learning specialist, science fair director, education consultant). Ms. Davis received her master's degree in science education and biology from the Florida Institute of Technology. Past honors include Florida Master Teacher, Brevard County Teacher of the Year, and Florida Association of Science Teachers Outstanding Teacher Award. She was also selected to travel to Japan as part of the Florida Commissioner of Education's Japanese study team. Ms. Davis has published articles in professional magazines and has presented on a variety of topics to state, national, and international audiences. She also leads the Brevard Science Advisory Council and serves on the Space Coast Science Education Alliance, the Space Camp Education Advisory Board, and the Space Congress Committee. Ms. Davis is married to Carey Horn and has a nine-year-old daughter, Kyla.

Raul Montes has been a teacher at Cocoa High School in the Brevard, Florida, School District since August 1978. He received his bachelor of arts degree in education degree from Florida Technological University (University of Central Florida) and has teaching certifications in physics, mathematics, and general science. The science department chair since 1988, Mr. Montes teaches a variety of physics, chemistry, and integrated science courses in addition to being the Earth Club Sponsor, the National Honor Society Sponsor, and the Brevard County School Science Fair director/teacher. Mr. Montes coaches swimming, boys' tennis, and boys' soccer at Cocoa High School. He is active on the Brevard Public Schools Integrated Science Writing Team, the Brevard County Science Advisory Committee, the Florida Department of Education Textbook Committee—Integrated Science and Chemistry, and the BSCS Design Study on Integrated Science at the High School Level advisory board. Mr. Montes and his wife, Elizabeth, have three children: Maren, Raul Jr., and Kylee.

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ATTACHMENT: FLORIDA SCENARIO

INTEGRATED SCIENCE I
PERFORMANCE STANDARDS

Strand 1: The Nature of Matter

A. Simple Stoichiometry and Equations
   The student will demonstrate an ability to:
   1. write chemical formulas.
   2. calculate formula mass.
   3. write and balance simple equations.
   4. show the mass relationships in a chemical equation.

B. Periodicity
   The student will demonstrate an ability to:
   1. differentiate between families and periods.
   2. explain the relationships of the elements in a family and period.
   3. use characteristics of an element to determine its placement in the periodic table.
   4. determine the valence electrons of an element's atoms based on its location in the periodic table.
   5. predict trends in the periodic table such as size and ionic tendency.

C. Atomic Structure and Chemical Bonding
   The student will demonstrate an ability to:
   1. model historical changes in the theory of atomic structure.
   2. identify the significance of oxidation numbers.
   3. differentiate between ionic and covalent bonding.

D. Electrostatics
   The student will demonstrate an ability to:
   1. investigate the nature of electrostatics.
   2. relate the law of electrostatics to experiments on atomic structure.

E. Acid/Base Systems
   The student will demonstrate an ability to:
   1. compare and contrast properties of acids and bases.
   2. identify the acidity and alkalinity of a substance using indicators.
   3. measure the strength of acid/base solutions using the pH scale.

Strand 2: Energy

A. Effects of Heat and Temperature
   The student will demonstrate an ability to:
   1. explain the relationship between temperature and heat.
   2. investigate the effects of heat on matter, such as change of state and thermal expansion.

B. Endothermic/Exothermic Reactions
 The student will demonstrate an ability to:
 1. compare endothermic to exothermic chemical reactions.
 2. identify examples of endothermic and exothermic chemical reactions in organic and nonliving systems.

C. Energy Needs in Living Systems
 The student will demonstrate an ability to:
 1. evaluate the energy content of various foods.
 2. describe how living systems use and transform different forms of energy.

D. Electromagnetic Radiation
 The student will demonstrate an ability to:
 1. identify the regions of the electromagnetic spectrum.
 2. relate the spectral characteristics and uses of the various regions of the electromagnetic spectrum.

E. Simple Circuits
 The student will demonstrate an ability to:
 1. design and construct simple circuits.
 2. identify the components of a circuit and describe the flow of current in the circuit.
 3. apply Ohm's law to simple circuits.
 4. relate simple circuits to integrated circuits.

F. Wave Interactions
 The student will demonstrate an ability to:
 1. use diagrams to explain reflection and refraction.
 2. predict wave behavior resulting from constructive and destructive interference.

Strand 3: Force and Motion

A. Work and Power
 The student will demonstrate an ability to:
 1. distinguish between work and power.
 2. apply the concepts of work and power to specific situations.

B. Simple Machine Applications
 The student will demonstrate an ability to:
 1. design and construct simple machines to perform specific tasks.
 2. apply knowledge of simple machines to biomechanics.

C. Kinematics/Dynamics (One Dimensional)
 The student will demonstrate an ability to:
 1. calculate the velocity and acceleration of a moving object.
 2. analyze the forces causing motion.
 3. explain the conversion of potential to and from kinetic energy for a moving object.

D. Newton's Law of Gravity
The student will demonstrate an ability to:
1. describe the relationship between mass, distance, and gravitational force.
2. distinguish between mass and weight.

E. Fluid Dynamics
The student will demonstrate an ability to:
1. summarize the contributions of Archimedes, Bernoulli, and Pascal to fluid mechanics.
2. apply Archimedes' principle to buoyancy and specific gravity.
3. apply Bernoulli's principle to lift and pressure.
4. apply Pascal's law to hydraulics.

Strand 4: Processes That Shape the Earth

A. Resource Depletion
The student will demonstrate an ability to:
1. identify natural resources and their uses.
2. categorize the use of resources as beneficial or detrimental to the earth and its ecosystems.

B. Geological Time
The student will demonstrate an ability to:
1. explain the geologic history of the earth using various geologic dating systems and their fossil evidence.
2. create a geologic time scale including major life forms and events.

C. Rock Cycle
The student will demonstrate an ability to:
1. explain the rock cycle, describing igneous, sedimentary, and metamorphic rocks and their interrelationships.
2. explain and distinguish between the formation of igneous, sedimentary, and metamorphic rocks.

D. Ocean/Atmosphere Interactions
The student will demonstrate an ability to:
1. review the hydrological cycle.
2. analyze the interrelationships between the atmosphere and hydrosphere.

Strand 5: Earth in Space

A. Origin of the Solar System
The student will demonstrate an ability to describe and evaluate current and historical theories of the formation of the solar system and its major and minor bodies.

B. Solar System/Minor Bodies
The student will demonstrate an ability to compare the characteristics of the planets and minor bodies.

C. Technology in Space Studies
   The student will demonstrate an ability to:
   1. analyze how space technologies have influenced the biological, earth, space, and physical sciences.
   2. explain how society has benefited from space technologies.

Strand 6: Processes of Life

A. Functions of Specific Human Cells
   The student will demonstrate an ability to:
   1. describe the relationship between structure and function of specific human cells.
   2. apply the organizational hierarchy to the human organism.

B. Cell Reproduction
   The student will demonstrate an ability to:
   1. discuss reasons for cell reproduction.
   2. summarize the cell cycle and explain the importance of interphase.
   3. illustrate the process of DNA replication and identify its importance for mitosis.

C. Mendelian Genetics
   The student will demonstrate an ability to:
   1. solve simple genetics problems using Punnett squares.
   2. predict the genotypes and phenotypes of offspring in monohybrid and dihybrid crosses.

D. Cellular Transport
   The student will demonstrate an ability to:
   1. explain cellular transport including endocytosis and exocytosis.
   2. describe the role of the cell membrane and the interaction of the cell with its environment.

E. Cellular Communication (Intracellular and Extracellular)
   The student will demonstrate an ability to:
   1. explain the need for intracellular communication.
   2. explain the role of molecules in intracellular communication.
   3. explain the role of hormones in cellular communication.
   4. explain the chemical and electrical communication between cells in the nervous system.

Strand 7: How Living Things Interact with Their Environment

A. Habitat and Niche
   The student will demonstrate an ability to:
   1. identify the ecological role of organisms in an ecosystem.
   2. describe the niche and habitat of various organisms in an ecosystem.

B. Taxonomic Keys
The student will demonstrate an ability to:
1. use a taxonomic key to identify extinct and extant organisms.
2. design and construct a taxonomic key.

Strand 8: The Nature of Science

A. Observe: Qualitative/Quantitative
The student will demonstrate an ability to:
1. distinguish between qualitative and quantitative observations.
2. record appropriate and accurate observations.

B. Classify
The student will demonstrate an ability to:
1. identify characteristics useful in classifying objects or phenomena.
2. develop a scheme for classification.
3. utilize a classification scheme to identify an object or phenomenon.

C. Measurement Systems
The student will demonstrate an ability to:
1. utilize SI measurement.
2. explain the relationships within and between SI units.

D. Experimental Design
The student will demonstrate an ability to:
1. design an experiment to test a hypothesis.
2. identify critical assumptions underlying an experimental design.
3. evaluate methods or strategies that may produce more precise results.

E. Hypothesize
The student will demonstrate an ability to:
1. formulate testable hypotheses.
2. identify the hypothesis that underlies an experimental design.

F. Identify/Control Variables
The student will demonstrate an ability to:
1. identify the variables in an experiment or observational situation.
2. describe methods to control variables in a specific experiment or situation.

G. Collect/Record Data
The student will demonstrate an ability to present data accurately in an appropriate table, chart, or graph.

H. Analyze Data
The student will demonstrate an ability to:
1. use and understand statistical analysis appropriate to the nature of the data.
2. evaluate data for the influence of bias or uncontrolled variables.

3. analyze graphs for accurate representation.
4. draw conclusions based on the available data.
5. make predictions based on conclusions from scientific experimentation.

I. Dimensional Analysis
The student will demonstrate an ability to:
1. identify and utilize units in quantitative measurement.
2. use units in equations and problem solving.

J. Follow Safety Procedures
The student will demonstrate an ability to:
1. exercise sound judgment with respect to safety.
2. comply with safety directions for each activity.

K. Use Science Equipment
The student will demonstrate an ability to:
1. recognize and safely use scientific equipment.
2. select the appropriate equipment for a specified task.

L. Historical/Social Implications of Science
The student will demonstrate an ability to:
1. explain that scientific study is based on the belief that rules can be discovered by careful, systematic study.
2. explain differences in scientific opinion on a given topic from the past or present.
3. recognize that testing, revising, and reevaluation are continuous processes in science.
4. understand that scientific investigation is part of human nature.
5. evaluate the social implications of controversial experimentation.
6. explain the importance of communicating scientific results within the scientific community and to the general public.

Integrated Science II
Performance Standards

Strand 1: The Nature of Matter

A. Quantum Theory
The student will demonstrate an ability to:
1. identify and explain the theories of Planck, Bohr, Einstein, and Heisenberg.
2. evaluate the need for the introduction of the Quantum Theory.
3. relate spectral analysis, properties of light, properties of matter, photoelectric effect, and x-ray analysis to the Quantum Theory.
4. apply Quantum Theory to the Bohr model and the wave-mechanical model of the atom.

B. Variations in Chemical Bonding
The student will demonstrate an ability to:

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1. identify and understand the four types of chemical bonding: ionic, covalent, hydrogen, and metallic bonds.
2. use the periodic table to predict the types of bonding that will occur between specific elements.
3. identify the bond types typically found in organic compounds.
4. describe simple organic compounds and their formulas.

C. Transmutation

The student will demonstrate an ability to:

1. understand the principles of radioactive decay and the synthesis of new elements.
2. write and balance nuclear equations.
3. explain the applications of radioactive elements.

D. Solution Chemistry

The student will demonstrate an ability to:

1. understand the effects of solute concentration on the physical properties of solutions.
2. identify factors that affect the degree of solubility and rate of solubility.
3. explain the role that electrolytes play in living systems.
4. understand the nature of acid/base systems including Arrhenius, Bronsted-Lowry, and Lewis theories.
5. perform calculations for pH.
6. investigate methods of determining acid/base concentrations.

E. Reaction Rates and Equilibrium

The student will demonstrate an ability to:

1. identify the factors that affect the reaction rates and equilibrium of systems, including concentration, surface area, agitation, particle size, temperature, and catalysts.
2. recognize different types of chemical reactions, i.e., combustion, neutralization, oxidation-reduction, single and double replacement, analysis, and synthesis.
3. calculate mass, volume, and mole relationships in chemical reactions.

F. Coulomb's Law

The student will demonstrate an ability to:

1. understand the application of Coulomb's Law as it relates to atomic structure.
2. explain the relationship of electron position to the energy of the electron.
3. use Coulomb's Law to compute forces between charged particles.

Strand 2: Energy

A. Electrochemical Processes

The student will demonstrate an ability to:

1. identify electrochemical processes and calculate cell potentials in redox reactions.

2. explain the electrochemical process in batteries, cells, the nervous system and brain, muscle tissues, photosynthesis, and respiration.

B. Energy Transformations

The student will demonstrate an ability to:

1. identify the characteristics of the various forms of energy including heat, electromagnetic, chemical, nuclear, and mechanical.
2. describe the methods of energy conversion.

C. Catalysts

The student will demonstrate an ability to understand the role catalysts play in chemical and living systems (enzymes).

D. Calorimetry

The student will demonstrate an ability to:

1. explain the transfer of heat in various systems.
2. identify the involvement of heat in specific heat, heat of vaporization, heat of fusion, heat capacity, heat of reaction, and combustion.
3. perform appropriate calculations involving heat.

E. Gas Laws and Kinetic Theory

The student will demonstrate an ability to:

1. make calculations based on the combined and ideal gas laws (Charles, Boyle, Gay-Lusac).
2. apply kinetic theory to molecular motion as it occurs in gas laws.

F. Laws of Energy and Matter

The student will demonstrate an ability to:

1. verify the conservation of energy.
2. verify the conservation of matter.
3. apply Einstein's equation to the conservation of energy and matter.

G. Resistance and Capacitance

The student will demonstrate an ability to:

1. describe the behavior of resistance and capacitance in parallel and series circuits.
2. identify the factors affecting resistance and capacitance.

Strand 3: Force and Motion

A. Friction, Drag, and Velocity

The student will demonstrate an ability to:

1. summarize the characteristics of friction, drag, and terminal velocity.
2. identify factors that contribute to friction and drag.
3. explore the effects of streamlining on terminal velocity.
4. show all motion is relative to a frame of reference.

B. Kinematics and Dynamics (Two Dimensional)

The student will demonstrate an ability to:

1. describe the nature of motion in terms of circular motion, projectile motion, and rotational motion.

2. explain simple harmonic motion.
3. describe the behavior of the pendulum mathematically.
4. describe the behavior of springs mathematically.

C. Conservation of Linear Momentum

The student will demonstrate an ability to:

1. distinguish between elastic and nonelastic collisions.
2. apply the $m_1 v_1 = m_2 v_2$ equation under both positive and negative conditions.
3. apply conservation concepts to everyday events such as auto wrecks, billiards, etc.

D. Rotational Systems

The student will demonstrate an ability to:

1. compare and contrast circular and rotational motion.
2. explain angular velocity, angular acceleration, and angular momentum.
3. design and construct a system illustrating circular and rotational systems and rotational equilibrium and apply it to everyday experiences.

Strand 4: Processes That Shape the Earth

A. Climate Systems

The student will demonstrate an ability to:

1. identify climate variations.
2. identify the reasons for climatic change.
3. research the effects of major climatic change in the past and speculate as to the possible causes.
4. predict possible climatic changes due to human intervention.

B. Coastal Erosion

The student will demonstrate an ability to:

1. identify the causes of coastal erosion.
2. describe typical coastal land forms.
3. evaluate human attempts to control coastal erosion.
4. debate the development of coastal areas.

C. Natural Solute/Solvent Systems

The student will demonstrate an ability to:

1. identify natural solute/solvent systems that affect the atmosphere, hydrosphere, and lithosphere.
2. explore the formation of Karst topography and geothermal systems.
3. determine the impact of hydrothermal vents on ocean chemistry and life forms.
4. describe the effects of gases released by natural and human activities on natural solute/solvent systems (volcanoes, combustion, etc.).

D. Earth Structure (Geomorphology)

The student will demonstrate an ability to model the various layers of

the earth and describe the differences among them.

E. Renewable and Nonrenewable Resources

The student will demonstrate an ability to:

1. differentiate between renewable and nonrenewable resources, citing examples.
2. calculate longevity of various nonrenewable resources, given current and predicted consumption.
3. explore solutions to the depletion of nonrenewable resources.
4. explore the effects of exceeding sustainable yield for a renewable resource.

Strand 5: Earth in Space

A. Planetary Motion

The student will demonstrate an ability to:

1. describe and model planetary motion in our solar system.
2. calculate the motions of the planets according to the laws of Kepler and Newton.
3. describe the effects of the relative motion of the earth, sun, and moon on biological activity.

B. Earth's Magnetism

The student will demonstrate an ability to:

1. demonstrate the earth's magnetic character and determine uses of this phenomena.
2. describe possible explanations for the earth's magnetic field.
3. explore the effects of the magnetic field on earth phenomena including the aurora and Van Allen radiation belts.
4. explore the effects of the magnetic field on organisms (i.e., migration).
5. predict future movements of the earth's magnetic poles based on historical data.
6. describe the evidence of seafloor spreading as it relates to the magnetic field.

C. Stellar Evolution

The student will demonstrate an ability to:

1. describe the formation of stars and identify the various stages of stellar evolution.
2. describe the effect of mass variation on stellar evolution.
3. explain how various mass stars end their life.
4. plot the location of a star on the H.R. diagram at various stages of stellar evolution.

D. Galactic Systems

The student will demonstrate an ability to:

1. describe the structure of spiral, elliptical, and irregular galaxies.

2. diagram the location of old stars, young stars, dust, and gas within different types of galaxies.
3. observe the large-scale distribution of galaxies within the universe.
4. describe the movement of galaxies.

Strand 6: Processes of Life

A. Meiosis

The student will demonstrate an ability to:

1. summarize the process of meiosis and understand its importance in maintaining chromosome number.
2. explain why DNA replication is necessary for meiosis to occur.
3. investigate the relationship between meiosis and genetic variation.
4. contrast gamete formation in males and females.
5. distinguish between mitosis and meiosis and note variations in plants and animals.

B. Chromosomes and Genes

The student will demonstrate an ability to:

1. integrate the chromosome theory of inheritance with Mendelian genetics.
2. formulate a statement describing the relationship between DNA, genes, and chromosomes.
3. differentiate between Mendelian and non-Mendelian genetics.
4. identify causes of human genetic disorders.
5. identify types of mutations and discuss possible results in gametic and somatic cells.
6. discuss the relationship between mutations and cancer.

C. Human Growth and Reproduction

The student will demonstrate an ability to:

1. trace the development and differentiation of the egg from fertilization to birth.
2. describe the changes that occur during infancy, childhood, and adolescence.
3. explain the reproductive cycles of males and females.
4. describe the effects of hormones on reproductive systems.
5. investigate the effects of aging on the various body systems.

D. Energy Transfers in Living Systems

The student will demonstrate an ability to:

1. compare the process of photosynthesis, respiration, and fermentation.
2. summarize the energy flow through the process of photosynthesis, respiration, and fermentation.
3. illustrate that energy flows through ecosystems, and materials cycle.

Strand 7: How Living Things Interact with Their Environment

A. Natural Selection

The student will demonstrate an ability to:

1. recognize that within a given population, individuals display genetic variation.
2. apply the concept of adaptation to reproductive success.
3. explain the role of the environment in natural selection.
4. compare natural selection to artificial selection.

B. Population Dynamics

The student will demonstrate an ability to:

1. list the conditions necessary to maintain Hardy-Weinberg equilibrium in a population.
2. calculate and predict allele frequencies within a stable population using the Hardy-Weinberg equation.
3. describe how changes occur within a gene pool (i.e., migration, genetic drift).
4. explain the role of limiting factors in controlling population growth.

C. Environmental Observation Technologies

The student will demonstrate an ability to explain technologies currently used to identify and measure various environmental features such as deforestation, pollution, drought, etc.

Strand 8: The Nature of Science

A. Observe: Qualitative/Quantitative

The student will demonstrate an ability to:

1. distinguish between qualitative and quantitative observations.
2. record appropriate and accurate observations.

B. Classify

The student will demonstrate an ability to:

1. identify characteristics useful in classifying objects or phenomena.
2. develop a scheme for classification.
3. utilize a classification scheme to identify an object or phenomenon.

C. Measurement Systems

The student will demonstrate an ability to:

1. utilize SI measurement.
2. explain the relationships within and between SI units.

D. Experimental Design

The student will demonstrate an ability to:

1. design an experiment to test a hypothesis.
2. identify critical assumptions underlying an experimental design.
3. evaluate methods or strategies that may produce more precise results.

E. Hypothesize

The student will demonstrate an ability to:

1. formulate testable hypotheses.
2. identify the hypothesis that underlies an experimental design.

F. Identify/Control Variables

The student will demonstrate an ability to:

1. identify the variables in an experiment or observational situation.
2. describe methods to control variables in a specific experiment or situation.

G. Collect/Record Data

The student will demonstrate an ability to present data accurately in an appropriate table, chart, or graph.

H. Analyze Data

The student will demonstrate an ability to:

1. use and understand statistical analysis appropriate to the nature of the data.
2. evaluate data for the influence of bias or uncontrolled variables.
3. analyze graphs for accurate representation.
4. draw conclusions based on the available data.
5. make predictions based on conclusions from scientific experimentation.

I. Dimensional Analysis

The student will demonstrate an ability to:

1. identify and utilize units in quantitative measurement.
2. use units in equations and problem solving.

J. Follow Safety Procedures

The student will demonstrate an ability to:

1. exercise sound judgment with respect to safety.
2. comply with safety directions for each activity.

K. Use Science Equipment

The student will demonstrate an ability to:

1. recognize and safely use scientific equipment.
2. select the appropriate equipment for a specified task.

L. Historical/Social Implications of Science

The student will demonstrate an ability to:

1. explain that scientific study is based on the belief that rules can be discovered by careful, systematic study.
2. explain differences in scientific opinion on a given topic from the past or present.
3. recognize that testing, revising, and reevaluation are continuous processes in science.
4. understand that scientific investigation is part of human nature.
5. evaluate the social implications of controversial experimentation.
6. explain the importance of communicating scientific results within the scientific community and to the general public.

Integrated Science III
Performance Standards

Strand 1: The Nature of Matter

A. Crystallography

The student will demonstrate an ability to:

1. grow crystals and describe their structures.
2. explain the significance of the unit cell to the shape of the crystal.

B. Dark Matter

The student will demonstrate an ability to:

1. discuss particles that could account for Dark Matter and describe their characteristics.
2. describe how Dark Matter is detected and measured.

C. Universal Forces

The student will demonstrate an ability to describe the nature of and the particle associated with each of the four fundamental forces: gravitational, electromagnetic, strong nuclear, and weak nuclear.

Strand 2: Energy

A. Fission/Fusion

The student will demonstrate an ability to:

1. compare fission and fusion as processes of energy production.
2. evaluate the possibility of fusion as a future source of energy.
3. write equations for fusion and fission reactions.

B. Energy Conversion Systems

The student will demonstrate an ability to:

1. assess the efficiency of energy transformations in complex systems.
2. apply thermodynamic principles to energy transformations.
3. discuss the increase of entropy within a system.

C. Duality of Light

The student will demonstrate an ability to:

1. distinguish between the wave and particle nature of light.
2. apply knowledge of the nature of light to new technologies.

D. Magnetic Fields

The student will demonstrate an ability to:

1. generate magnetic fields by electromagnetic induction (electromagnet).
2. calculate the force on a moving charge in a magnetic field.
3. describe how magnetic fields vary with the distance away from magnetic field sources.
4. apply magnetic field theory to electric motors, generators, and solenoids.

E. Electric Circuit Application

The student will demonstrate an ability to:

1. measure the energy and calculate the cost required to operate an electrical device.
2. design an experiment that deals with efficiency of an electrical device.
3. construct an advanced electric circuit and describe the behavior of electric charge and current within the circuit.
4. calculate and measure the voltage, current, charge, resistance, and capacitance of a circuit.
5. evaluate the energy efficiency of different types of air conditioning systems.

F. Optics and Sound Applications

The student will demonstrate an ability to:

1. apply the Doppler Effect to changes in relative velocity, frequency, and wavelength of sound waves.
2. calculate the speed of sound as it varies with temperature and media.
3. apply the properties of wave interference, refraction, reflection, and diffraction in sound and light.
4. use Snell's law to calculate incident and refracted angles of a light ray at the interface between media of varying densities.
5. construct an optical bench using mirrors and lenses, showing the relationship between focal length and the object/image height and distance.
6. design a presentation illustrating optical and acoustical applications in technology and biology (e.g., fiber optics, ultrasound, photography, astronomy, vision, etc.).

Strand 3: Force and Motion

A. Kinematics/Dynamics (Applications)

The student will demonstrate an ability to design and carry out an experiment to measure the forces within living and nonliving systems.

B. Conservation of Rotational Momentum

The student will demonstrate an ability to:

1. describe how rotational inertia affects rotational momentum.
2. design a presentation illustrating the characteristics of rotational momentum.

C. Special Relativity

The student will demonstrate an ability to:

1. describe and calculate the effects of near-light speed velocities on the mass, length, and time frame of objects in relative motion.
2. explain the time implications for simultaneity.
3. compare special relativity with general relativity.

D. Electric Motors

The student will demonstrate an ability to:

1. design, construct, and evaluate an electric motor.
2. explore factors that affect the efficiency of an electric motor.

E. Electric Power Distribution
The student will demonstrate an ability to:
1. design and build a generator.
2. trace the path of electricity from generator to consumer and evaluate efficiency.
3. identify the uses of generators.

Strand 4: Processes That Shape the Earth

A. Radioactive Dating
The student will demonstrate an ability to:
1. explain radioactive decay and how it relates to the dating of organic and inorganic material.
2. investigate various isotopes used in radiometric dating and evaluate their relative accuracies.

B. Ice Ages (Past and Future)
The student will demonstrate an ability to:
1. discuss the ice ages as evidence of climatic change.
2. discuss how humans would deal with an ice age or other major climatic change.
3. predict future climate changes on the basis of historical data and human impact.
4. describe how the ice ages have altered ecosystems and topography.

C. Human Interaction with Earth's Resources
The student will demonstrate an ability to present examples of how human intervention has altered distribution of earth's resources.

Strand 5: Earth in Space

A. Cosmology
The student will demonstrate an ability to:
1. analyze the theories of the formation and possible end of the universe(s).
2. describe the technology used to observe, analyze, and develop theories of the cosmos.
3. understand that the cosmos is the "lab" of astronomers because the extreme conditions of stars cannot be recreated on earth.

B. Grand Unified Theory
The student will demonstrate an ability to discuss the basis of the Grand Unified Theory.

C. Theories of Life in the Universe
The student will demonstrate an ability to:
1. describe the conditions necessary for the development of life as we know it and evaluate the probability of life developing elsewhere in the universe.

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2. predict the likelihood of contacting extraterrestrial intelligent life.

D. Chemistry of the Universe

The student will demonstrate an ability to investigate the chemical composition of stars based on their spectral fingerprints.

Strand 6: Processes of Life

A. Transcription and Translation

The student will demonstrate an ability to:

1. build a manipulative model to demonstrate the processes involved in transcription and translation.
2. explain how mutations may cause changes in the products of transcription and translation.
3. distinguish among mRNA, tRNA, and rRNA.
4. relate transcription and translation to the replication of DNA and RNA viruses and retroviruses.
5. summarize the relationship between DNA, RNA, amino acid sequence, and proteins.

B. Biotechnology

The student will demonstrate an ability to:

1. create a presentation evaluating current and future applications of biotechnology.
2. discuss the ethical, moral, social, and legal issues raised by the development of new biotechnologies.

C. Synergism

The student will demonstrate an ability to:

1. illustrate integration of body systems to maintain life functions.
2. relate cell function to homeostasis.

Strand 7: How Living Things Interact with Their Environment

A. Epidemiology

The student will demonstrate an ability to:

1. trace the development of modern medicine and the effects on disease in the twentieth century.
2. illustrate the cause, course, transmission, treatment, and social-historical ramifications of a plant or animal disease.

B. Causes of Mutations

The student will demonstrate an ability to:

1. identify various causes of mutations.
2. evaluate the potential effects of natural and humanmade mutagens.
3. understand that mutations may be beneficial, detrimental, or insignificant.

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C. Mechanisms of Evolution
The student will demonstrate an ability to:
1. describe different mechanisms and theories of evolution.
2. evaluate the evidence that supports the modern theory of evolution.

D. Interdependence of Living Things
The student will demonstrate an ability to:
1. explain ecosystem stability in terms of variables such as population size, species richness, diversity, and productivity.
2. describe the role of specific ecosystems.
3. summarize the types of symbiosis and give examples.

E. Environmental Ethics
The student will demonstrate an ability to:
1. discuss the importance of maintaining biodiversity as a method for maintaining plant and animal resources.
2. discuss the positive and negative impact of human activity on the natural environment.

Strand 8: The Nature of Science

A. Observe: Qualitative/Quantitative
The student will demonstrate an ability to:
1. distinguish between qualitative and quantitative observations.
2. record appropriate and accurate observations.

B. Classify
The student will demonstrate an ability to:
1. identify characteristics useful in classifying objects or phenomena.
2. develop a scheme for classification.
3. utilize a classification scheme to identify an object or phenomenon.

C. Measurement Systems
The student will demonstrate an ability to:
1. utilize SI measurement.
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D. Experimental Design
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1. design an experiment to test a hypothesis.
2. identify critical assumptions underlying an experimental design.
3. evaluate methods or strategies that may produce more precise results.

E. Hypothesize
The student will demonstrate an ability to:
1. formulate testable hypotheses.
2. identify the hypothesis that underlies an experimental design.

F. Identify/Control Variables
The student will demonstrate an ability to:

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1. identify the variables in an experiment or observational situation.
2. describe methods to control variables in a specific experiment or situation.

G. Collect/Record Data

The student will demonstrate an ability to present data accurately in an appropriate table, chart, or graph.

H. Analyze Data

The student will demonstrate an ability to:

1. use and understand statistical analysis appropriate to the experience of the student and the nature of the data.
2. evaluate data for the influence of bias or uncontrolled variables.
3. analyze graphs for accurate representation.
4. draw conclusions based on the available data.
5. make predictions based on conclusions from scientific experimentation.

I. Dimensional Analysis

The student will demonstrate an ability to:

1. identify and utilize units in quantitative measurement.
2. use units in equations and problem solving.

J. Follow Safety Procedures

The student will demonstrate an ability to:

1. exercise sound judgment with respect to safety.
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1. recognize and safely use scientific equipment.
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L. Historical/Social Implications of Science

The student will demonstrate an ability to:

1. explain that scientific study is based on the belief that rules can be discovered by careful, systematic study.
2. explain differences in scientific opinion on a given topic from the past or present.
3. recognize that testing, revising, and reevaluation are continuous processes in science.
4. understand that scientific investigation is part of human nature.
5. evaluate the social implications of controversial experimentation.
6. explain the importance of communicating scientific results within the scientific community and to the general public.

Source: Brevard Public Schools

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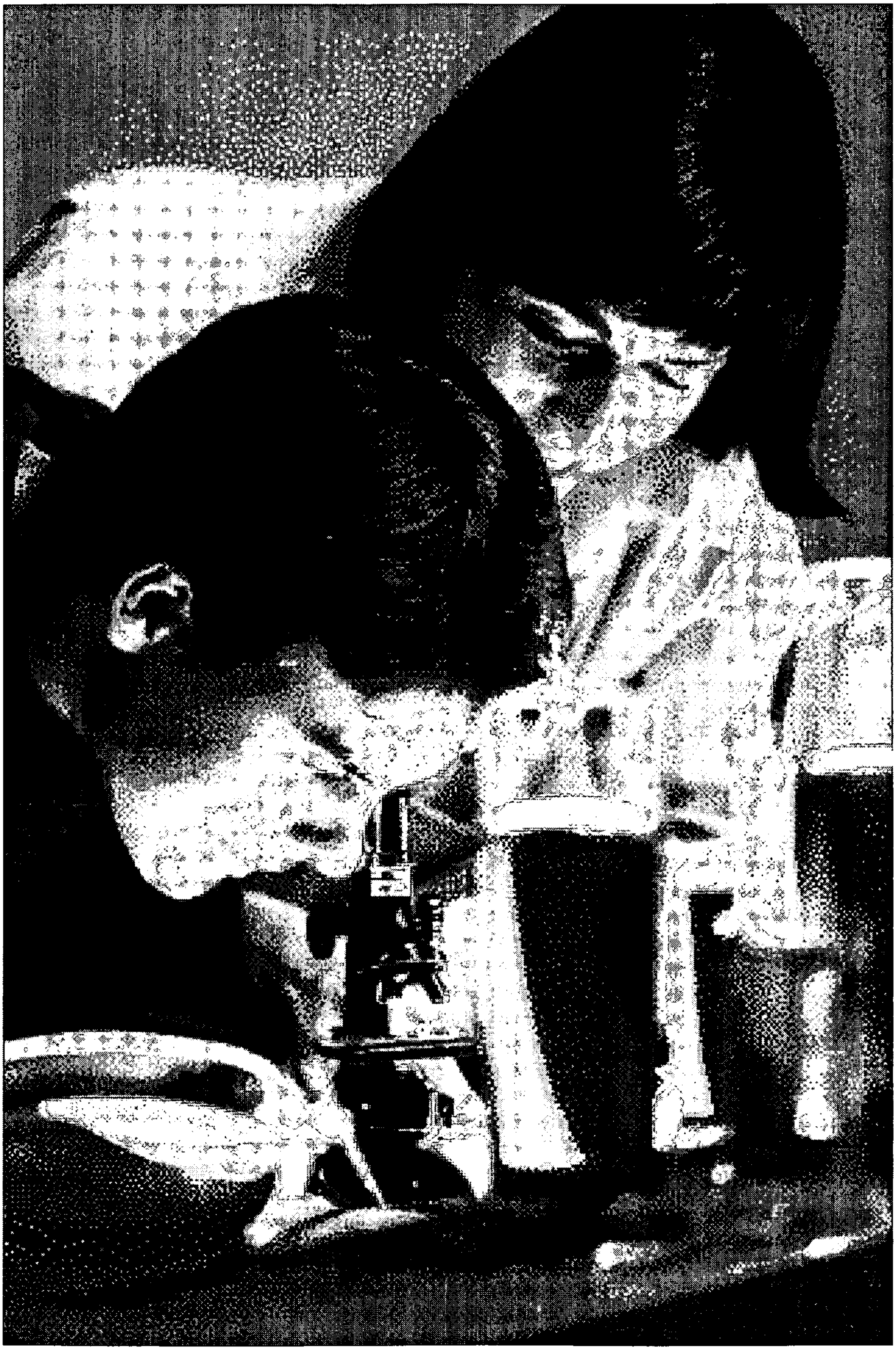

Concluding Remarks

As you begin your journey in integrated science or continue one that you began earlier, keep in mind five major ideas:

- Our overall goal is to enhance students' learning of science.
- Teachers of integrated science need support in a number of areas in an ongoing manner.
- Don't worry about the definition of integrated science; coherence is the important issue.
- Keep an open mind.
- Change takes time.

Our goal for students is an improved understanding of science. We know that integrated science engages a diversity of students and helps them make connections (and consequently, make meaning) of much of what they experience in the natural world. If they are making connections and constructing a conceptual understanding of science, this should contribute broadly to their personal and academic experiences.

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We know that to have a successful program in integrated science, it takes exceptional teachers. We also know that teachers of integrated science need ongoing support from other teachers, from the school administration, and from the district. One ongoing need of teachers who teach integrated science is the time and funding to learn the content and to learn the most effective ways to teach the content. Teachers also need support to develop a network of colleagues and community professionals with whom to collaborate. Teachers need to know that the district is willing to purchase the appropriate instructional materials and supplies, and teachers need the flexibility to structure the school day to best support the nature of the classroom work as well as the collaborative aspect of the work.

The precise definition of integrated science that you use is not that important. Whether your program integrates the disciplines of science across a week, a quarter, a semester, or a year is not the most important criteria. The important goal is that the course of study, regardless of the grain size of integration, be coherent—that the integration that occurs is logical and carefully crafted.

We know that chance favors the prepared mind, and a prepared mind is an open one. In the integrated science experience, this is a major operating principle for students, teachers, and administrators. Be prepared to see things differently, respond to situations differently, respond to questions differently, respond to the content differently, and respond to students differently. Being open, both with respect to the nature of the content and to the mechanics of such a program, will provide teachers, students, and administrators the opportunity for improved science teaching and learning.

Change takes time. It takes time for teachers to prepare to teach, it takes time for students to be accustomed to a new way of learning. It takes parents time to accept that learning science can be different from the way they learned science, it takes principals and district administrators time to understand how to best support the change. Introduce the changes in a realistic time line that allows for transitions and preparations for all the stakeholders. Change is a process, and that process needs to be flexible enough to be informed along the way by how things unfold. Give yourself, your colleagues, and other stakeholders the gift of time.

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APPENDIX A

Using the Concerns-Based Adoption Model When Implementing Integrated Science Programs

by Susan Loucks-Horsley and Rodger W. Bybee

One dimension of the Concerns-Based Adoption Model (CBAM) is called Stages of Concern. School personnel implementing a new integrated science curriculum, for example, may express these stages as follows: When teachers are first introduced to the new curriculum, they need information. They need to know expectations and whose support they can count on. They will ask, What is it? What will it mean for me? As they begin to learn and use the integrated science materials, their management concerns increase and they ask, Why is it taking so much time? How can I better manage my students and these materials? They often feel frustrated and uncoordinated. Once they have mastered the program, they begin asking whether they are doing the best job they can for their students and what changes they can make to do an even better job. Figure A:1 describes each of the seven Stages of Concern with respect to an integrated science program.

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STAGES OF CONCERN:
EXPRESSIONS OF CONCERN ABOUT AN
INTEGRATED SCIENCE CURRICULUM

Expression of Concern		
6	Refocusing	I have ideas about something that would work even better.
5	Collaboration	I am concerned about relating what I am doing with what other teachers are doing.
4	Consequence	How is my use of the program affecting students? What adjustments can I make?
3	Management	I seem to be spending all my time getting material ready.
2	Personal	How will implementing an integrated science program affect me?
1	Informational	I would like to know more about the integrated science program.
0	Awareness	I am not concerned about integrated science.

Adapted from: Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987). *Taking charge of change*. Alexandria, VA: Association for Supervision and Curriculum Development.

Figure A:1 Stages of Concern: Expressions of Concern about an Integrated Science Curriculum.

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Teachers' expressing concern suggest the kind of help they need. In years of implementing new science programs at BSCS, we have learned that several activities, timed appropriately, can be helpful. Some of these are

- creating awareness among teachers, administrators, and the broader school community;
- providing direction and clear expectations;
- planning and arranging for initial professional development;
- acquiring, organizing, and distributing materials;
- demonstrating, coaching, and problem solving;
- providing opportunities for teacher sharing, additional professional development, and renewal;
- monitoring and troubleshooting; and
- evaluating.

We discuss these activities in the following sections, as they relate to implementing an integrated science program.

Creating Awareness

When introduced to an integrated science program, teachers' first questions will be What is it? and What does it mean for me?—typical informational and personal concerns. These concerns can be addressed in short, interactive meetings where teachers can get a feel for the new program, see some of the materials being taught, and have their questions answered. These sessions need to clarify the core components (that is, what teachers need to do to teach the curriculum well), dates for professional development and start-up, the kind of help they can expect to receive, where they will get the materials, and the commitment of administrators to the new program. This information can help teachers understand and accept the change. Teachers who are currently using or have used the curriculum can talk to the new teachers, giving them an image of what the program looks like, what problems they are likely to encounter, and what it will feel like to use. The discussion helps resolve concerns about whether they can really do it.

Administrators and others in the community will have the same kinds of awareness and information concerns about an integrated approach to science. They can benefit from awareness meetings held separately from those for teachers because the same kind of detail is

unnecessary. Sessions need to describe what these stakeholders can expect to see in science classrooms, what kind of help they can give teachers, and how important their understanding and support will be to the program's success.

PROVIDING DIRECTION AND CLEAR EXPECTATIONS

What is expected of me and when? are questions typically heard at the beginning of implementing a new program. Clear personal concerns, these need to be addressed by people in authority. Typical questions include What is expected of science teachers? Will I have to use all of the materials, only certain ones, or can I just use what I want to use? Will I have to use the whole program the first time through? Can I still use my favorite units from my old curriculum? my favorite textbook? my favorite tests? Will I be expected to do everything perfectly the first time I use the materials, or will it be understood that early "bumps" will smooth out with experience? How will my evaluation be influenced by the new curriculum? Will there be any assessment and, if so, how will its content relate to that of the new curriculum? These are just some of the questions that can be anticipated. Answers to these questions will provide clear direction for teachers, while letting them know that they will be supported in what they are doing.

PLANNING FOR PROFESSIONAL DEVELOPMENT

Initial professional development sessions should address teachers' management concerns: This helps them know what they will need to do to use the program. The best session leaders are people who have actually used the curriculum, who can answer the What-do-you-do-when or What-would-you-do-if questions. Learning to teach an innovative program such as an integrated approach to science requires teachers first to handle the materials, and second to practice new strategies. They need answers to scheduling, classroom management, and materials management questions.

If administrators are going to be helping teachers, they will need professional development too. They need to know what the materials are for the curriculum, what classrooms will look like when it is being taught, and how they support teachers who may feel frustrated and uncoordinated, which may extend through their first year.

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ORGANIZING MATERIALS

Because laboratory activities are the core of an integrated science program, it will depend heavily on materials to make it work. Teachers using the program will have many questions about equipment and materials soon after they know a decision has been made to implement the program. These management concerns can be greatly reduced by

1. Ordering the materials and equipment necessary for the program as far in advance as possible.
2. Setting up a storage system specifically for the integrated program unless a well-established procedure already has been set up in the science department. Are items grouped by unit? by activity? Are they clearly labeled?
3. Determining who is responsible for
   - Setting up the materials and equipment for each laboratory activity. Usually, one person can set up materials for other members of the department if everyone is on the same teaching schedule.
   - Cleaning up and putting away the items.
   - Inventorying and reordering materials and equipment for the next year.
4. Establishing a petty cash procedure so that items can be purchased from the local supermarket and discount stores.

Someone at the school or central office should set up a file for information related to the equipment and materials needed for the integrated science program. This would include catalogs, equipment lists, and notes about where and how to obtain the materials needed for the program. Sources of materials change over time, so it is important that the person who maintains this file is ready to troubleshoot equipment and materials problems as they arise. Nothing is more discouraging to a teacher, nor raises more management concerns, than being unable to obtain materials necessary for a laboratory-oriented program.

DEMONSTRATING, COACHING, AND PROBLEM SOLVING

Management concerns extend far beyond initial awareness and use. In fact, it is not unusual for teachers to feel disorganized through their first year in the program. That is why they need more than just initial professional development to help them master the curriculum and its requirements.

There are several ways to provide ongoing support. Classroom observation creates a good opportunity to encourage a teacher, point out things that are going well, and give ideas for improving. Coaching by peers as well as by someone in a leadership role also can help, although the ability of peers to be helpful is limited by how experienced and competent they themselves are with the new program. Classroom demonstrations can give teachers a better idea of how various strategies can help them get students involved with the materials in meaningful ways.

Providing More Professional Development Opportunities

Teachers continue to need support after they become comfortable with the new curriculum. They may have few concerns about the curriculum and need some new stimulation; or they may be concerned about the impact the curriculum is having on their students. In fact, it is only when teachers have mastered the activities and materials of a new program that they can pay full attention to student thinking and learning. Once logistics and procedures are on "automatic pilot," teachers can pay closer attention to concept formation, higher-order thinking, and students' ability to apply what they have learned. It is one thing for students to go through the activities and be able to answer a few questions. It is far more difficult for them to develop new concepts and ways of understanding science content, to be able to read and ask good questions, and to apply their new learning to their own lives. Teachers can benefit from opportunities to focus on how their students are thinking through sharing and discussing student work, writing about and analyzing their teaching dilemmas, or viewing videos of their and others' classrooms. Examining their teaching practice once management concerns are resolved can be an effective way to improve student learning.

Monitoring and Troubleshooting

Continual monitoring is needed to sustain a new program. Teachers do not always reach out when they need or want help—often they are too busy or may not admit that they cannot do everything perfectly. People in support roles need to "be out there," to be present, accessible, and useful to both teachers and administrators.

EVALUATING THE IMPLEMENTATION PROCESS AND STUDENT LEARNING

Someone needs to ask the hard questions: How are we doing with the curriculum and, even more difficult, how are our students doing? Experience with similar changes suggests that teachers will have some difficulties the first year they use an integrated science curriculum, so it is unlikely that student achievement will improve substantially. It makes sense to spend the first year assessing how teachers are doing, how their concerns change, and how they use the components of the curriculum.

After the first year, it is time to begin to closely look at student learning. Here, people in support roles play an especially important role, given that the curriculum does not lend itself to standard measures of science achievement. Different strategies can be used to track learning, strategies that teachers may not routinely use. Examining student work products such as laboratory investigations, development of performance assessments and rubrics for key science concepts and inquiry skills, and structuring and analyzing student portfolios are all ways to examine student learning. A systematic approach to assessment that involves teachers in clarifying student learning goals and the ways students can demonstrate their achievement can provide critical feedback for improving the use of the curriculum by teachers.

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APPENDIX B

A Short Cut for Model IV

If an individual teacher or the entire biology department at a small high school is considering implementing one integrated science unit at the end of a tenth-grade biology course, the process for planning and implementation that we describe in Chapter 3 could be scaled back considerably with respect to both scope and time. A large district that is considering a major change for all high schools might have one high school pilot the process for a year before it commits its resources to the implementation of integrated science on a larger scale. Regardless of the scale, the major steps still would include reflecting, planning, and taking action; the process might be similar to the following:

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1. First, you would reflect on your own goals for science education, specifically what you want students to know and be able to do.

   You might consider the following questions:

   - How might an integrated science unit help me meet the goals I have for students?
   - What are the likely hurdles?
   - What are the tradeoffs—if I teach this, what is it that I will not have time to teach?
   - Am I prepared to teach such a course?
   - What are my students likely to learn in such a unit that they are not learning in my course right now?
   - Will it be worth it?

2. If, after your initial reflections, you still are excited about the prospects of integrated science, the next step is to develop your personal rationale for implementing such a unit. This rationale will be important as you continue conversations with other stakeholders such as your principal, your students, their parents, and other colleagues in your department. Your personal rationale will draw heavily on your reflections from Step 1 and should include your ideas about why you feel this unit is important to your students.

3. It may be beneficial to complete a short version of the needs assessment (see Appendix C) so that, as you proceed, your subsequent decisions are well-informed ones. As you review the survey, select five to ten questions from the relevant sections to use as your abbreviated version. For example, you might want to complete the teacher section yourself as well as ask some other teachers to complete it. It may be a good idea to have the students in one of your classes complete the student section and to have your principal complete the administrator's section. After the needs assessments are complete and you have analyzed the results, you will be better able to design an effective unit and be better able to anticipate possible concerns of other teachers, students, and principals. You may want to expand your survey to include the district science supervisor.

4. Next, you are ready to design a unit in enough detail so that you know what content you would cover and what types of ques-

tions the students might develop. You may be selecting a unit of study from your biology curriculum and then expanding it to include the related, integrated content. For example, in your ecology unit, you may take the topic of wildfires and expand the unit to include many aspects of fire that you do not typically include in your biology class but that are relevant to the investigation. This might include detailed examination of combustion, heat transfer, the flow of energy, and the chemical changes that occur in organic matter during intense fire.

In addition to outlining the content of the unit, you should outline your specific learning goals for students and correlate these goals with the set of standards in use in your district. It also is important at this stage to design an appropriate assessment task for the unit, as a way of measuring your students' success.

5. It will be important to identify resources for teaching the unit.

6. Depending on the protocol for your school or district, once your goals and the unit are outlined, this would be an appropriate time to seek permission, if necessary, from your principal to proceed with the unit.

7. Now you are ready to teach the unit and evaluate the results with respect to teaching and learning.

8. When you have completed the unit, you can reflect on your own experience, your students' experience, and the assessment results. Based on this information, you now have the opportunity to revise your unit before teaching it again.

APPENDIX C

A Needs Assessment for Integrated Science

developed by Kathy Comfort and Eric Anderson

GUIDELINES FOR USING THIS INSTRUMENT

You can conduct a needs assessment to help your leadership team decide whether an integrated science program is appropriate for your school or district. A needs assessment examines the needs of all the stakeholders affected by the decision and how prepared they are for change. For details on using this instrument, refer to Chapter 3 of this guide.

The following sets of statements represent a database from which you can select items to design a needs assessment. Each numbered item consists of two statements that represent a range of ideas with respect to a particular issue. For example, one item articulates a range of confidence that a teacher has about teaching science.

The instrument that you develop for the individual and group responses should include a variety of these numbered items and not just the items that are easy to answer and for which it is easy to reach consensus. This tool will be valuable only if you ask some hard questions.

The database is organized according to stakeholders, so there are a set of statements for teachers, another set for students and so on. It would be most effi-

cient to develop your needs assessment from the RTF file of this appendix, which is available from the BSCS Web site (www.bscs.org). From the RTF file, you can copy and paste the selected questions into another file to create you own needs assessment.

Each numbered item has been constructed as a Leichert scale from 1 to 5. Individuals should respond to each pair of statements twice—first according to how he or she views the present situation and then a second time according to what he or she thinks the situation should be.

Example 1. I feel confident about my understanding of concepts in one of the following: biology, chemistry, physics, and earth science.

5. I feel confident about my understanding of concepts in all of the following: biology, chemistry, physics, and earth science.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Statements for Teachers

1 1. I have ineffective relationships with other teachers.

5. I have very effective relationships with other teachers.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

2 1. I have an ineffective relationship with my principal.

5. I have a very effective relationship with my principal.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

3 1. I generally have poor relationships with my students.

5. I generally have excellent relationships with my students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. I feel confident about my understanding of concepts in one of the following: biology, chemistry, physics, and earth science.

5. I feel confident about my understanding of concepts in all of the following: biology, chemistry, physics, and earth science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

5 1. I organize my teaching around science content, much like the organization of a science textbook.

5. I organize my teaching around themes like systems, change, water, and energy.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

6 1. I believe that a high school science education is only for students who are preparing for a career in science.

5. I believe that a high school science education is for all students regardless of their present choice of careers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

7 1. I maintain responsibility and authority.

5. I share the responsibility for learning with students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

8 1. I encourage competition among students.

5. I encourage cooperation and shared responsibility among students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

9 1. I make decisions about what to teach my students based on the content of a textbook.

5. I make decisions about what to teach my students based on content linked to Standards or Benchmarks

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

10 1. My district office makes all decisions about professional development opportunities that are provided.

5. In my district, teachers are the source of ideas about professional development opportunities that are provided.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

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11 1. My district office uses only external experts for the professional development of teachers.

5. In my district, teachers plan and facilitate professional development opportunities in conjunction with external experts.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

12 1. My district office and the local school board make all decisions about curricular change.

5. In my district, teachers are the facilitators of curricular change.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

13 1. I see no need to help my students make connections among the disciplines of science.

5. An understanding of the connections that exist between the disciplines of science is essential to the development of a student's scientific literacy.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

14 1. The primary basis for the organization of my teaching is district curriculum guides and/or the scope and sequence of my textbook.

5. I select and adapt curriculum that helps me accomplish the goals of my teaching.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

15 1. I understand and respond to the needs of my students as a group.

5. I understand and respond to each student's needs, experiences, and strengths.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

16 1. My teaching focuses on students' acquisition of knowledge.

5. My teaching focuses on students' understanding and use of scientific knowledge, ideas, and inquiry processes.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

17 1. I present scientific knowledge through lecture, text, and demonstration.

5. I guide students in active and extended scientific inquiry.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

18 1. I ask students to recite acquired knowledge.

5. I provide opportunities for students to engage in scientific discussion and debate.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

ERIC

19 1. I test students for factual information at the end of the unit or chapter.

5. I continuously assess student understanding.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

20 1. In the last five years, I have not attended any classes or read any books that increased my understanding about a topic in science.

5. In the last five years, I have attended classes and/or read books that increased my understanding about a topic in science at least five times.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

21 1. In the last five years, I have not received instruction that improved my abilities to teach science.

5. In the last five years, I have received instruction that improved my abilities to teach science five times or more.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

22 1. Of the professional growth activities I have participated in during the last five years, the majority have consisted of individual, unconnected, one- to two-hour events.

5. Of the professional growth activities I have participated in during the last five years, the majority have consisted of a variety of year-long, coherent classes, workshops, or institutes.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

23 1. I never team teach.

5. I team teach daily or weekly.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

24 1. I seldom talk with other teachers about how to improve my teaching.

5. I talk daily or weekly with other teachers about how to improve my teaching.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

25 1. My district uses only multiple choice tests to measure the science achievement of students.

5. My district uses a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

26 1. In my classroom, I use only multiple choice tests to measure the science achievement of students.

5. In my classroom, I use a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

27 1. I use the results of classroom assessments to assign students a grade.

5. I use the results of classroom assessments to improve my teaching and provide detailed feedback to students about their learning.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

28 1. I communicate student achievement to parents only via grades on report cards.

5. I communicate student achievement to parents using results from a variety of assessments, such as performance tasks and portfolios.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

29 1. I communicate achievement to students by telling them their grades.

5. I provide students with opportunities to evaluate their own learning.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

30 1. The resources and facilities at my school are not sufficient for me to teach high-quality inquiry science.

5. The resources and facilities at my school are sufficient for me to teach high-quality inquiry science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

31 1. In my school, students are tracked according to their ability on achievement tests or previous grades in science classes.

5. In my school, students are free to choose which science courses they take.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

32 1. Students can graduate from my school without significant instruction in any one or more of the following subjects: physical science, life science, earth science.

5. To graduate from my school, students must have significant instruction in all of the following subjects: physical science, life science, earth science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

STATEMENTS FOR STUDENTS

1 1. I generally have poor relationships with my science teachers. | 5. I generally have excellent relationships with my science teachers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

2 1. Science is not important to me because I will not use it in my career. | 5. Science is important to me because I will use it in my career.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

3 1. I do not like learning science. | 5. I enjoy learning science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. My teacher mostly lectures and gives us worksheets. | 5. In my science class, we do hands-on labs and extended projects (research, team activities) most of the time.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

ERIC Full Text Provided by ERIC

5 1. I haven't learned very much in science. 5. I have learned a lot in science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

6 1. I know that science is biology, chemistry, physics, and earth science. 5. The science topics that interest me the most are topics like the ozone that include content from each of the sciences.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

7 1. My teacher does not care whether I learn science or not. 5. My teacher cares about each student's learning.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

8 1. In my science class, most of my time is spent listening to my teacher and answering questions from the book or worksheets. 5. In my science class, most of my time is spent conducting lab experiments and discussing science topics with other students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

9 1. In my science class, I am usually unsure whether or not I learned something.

5. In my science class, I usually know whether or not I learned something.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. I want to take biology, chemistry, physics, and earth science.

5. I would like to take science classes that have all the sciences in them every year.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

STATEMENTS FOR ADMINISTRATORS

1 1. I generally have ineffective relationships with other administrators.

5. I generally have very effective relationships with other administrators.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

2 1. I generally have ineffective relationships with science teachers.

5. I generally have very effective relationships with science teachers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

3 1. I believe that a high school science education is only for students who are preparing for a career in science.

5. I believe that a high school science education is for all students regardless of their present choice of careers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. I believe that a high school science education is not essential.

5. I believe that a high school science education is at least as essential as an education in mathematics or English.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

5 1. Teachers should maintain responsibility and authority.

5. Teachers should share the responsibility for learning with students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

6 1. Teachers should encourage competition among students.

5. Teachers should encourage cooperation and shared responsibility among students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

7 1. Students should study biology, chemistry, physics, and earth science.

5. Students should take science classes that have all the sciences in them every year.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

8 1. Science is biology, chemistry, physics, and earth science.

5. Science that blurs the boundaries of the disciplines reflects the reality of the natural world.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

9 1. My district uses only multiple choice tests to measure the science achievement of students.

5. My district uses a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. Teachers should use only multiple choice tests to measure the science achievement of students.

5. Teachers should use a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

11 1. Teachers should use the results of classroom assessments to assign students a grade.

5. Teachers should use the results of classroom assessments to improve their teaching and provide detailed feedback to students about their learning.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

ERIC

12 1. Teachers should communicate student achievement to parents only via grades on report cards.

5. Teachers should communicate student achievement to parents using results from a variety of assessments, such as performance tasks and portfolios.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

13 1. Teachers should tell students their grades.

5. Teachers should provide students with opportunities to evaluate their own learning.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

14 1. Parents in my community would not support their students enrolling in classes that integrate concepts from biology, chemistry, physics, and earth science.

5. Parents in my community would support their students enrolling in classes that integrate concepts from biology, chemistry, physics, and earth science.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

15 1. My district uses very little of its Title II money for science professional development.

5. My district uses at least 40 percent of its Title II money for science professional development.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

16 1. My district does not apply funds other than Title II funds to high school science professional development.

5. My district applies funds other than Title II funds to high school science professional development.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

17 1. Science professional development in my district is targeted only to teachers.

5. Science professional development in my district targets both teachers and administrators.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

18 1. My district provides professional development for high school teachers primarily in the form of one- to two-hour discrete workshops or by sending teachers to conferences or conventions.

5. My district has a sustained, ongoing system of professional development for high school science teachers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

ERIC

19 1. My district has a history of engaging in projects of curricular or professional growth change, then abandoning them before real change is made.

5. My district has a history of engaging in projects of curricular or professional growth change, and completing and sustaining them.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Statements for Parents

1 1. I generally have an ineffective relationship with my child's science teacher.

5. I generally have an effective relationship with my child's science teacher.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

2 1. I have a poor relationship with the administrators at my child's school.

5. I have a good relationship with the administrators at my child's school.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

3 1. I think that my child's science education is not important for his or her success in life.

5. I think that my child's science education is very important for his or her success in life.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. Science was one of my least favorite subjects in high school.

5. Science was one of my favorite subjects in high school.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

5 1. I want my child to take only biology, chemistry, physics, and earth science classes.

5. I want my child to take science classes that have all the sciences in them every year.

How I view the present status

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

How I think it should be

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

6 1. In the last two years, I have not attended any school functions (open house, athletic event, concert) and/or PTA meetings.

5. In the last two years, I have attended at least ten school functions (open house, athletic event, concert) and/or PTA meetings.

How I view the present status

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

How I think it should be

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

7 1. I think that science is biology, chemistry, physics, and earth science.

5. I think that biology, chemistry, physics, and earth science topics connect with each other and with other nonscience topics.

How I view the present status

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

How I think it should be

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

8 1. I do not want my child to take classes that integrate concepts from biology, chemistry, physics, and earth science.

5. I would support my child enrolling in classes that integrate concepts from biology, chemistry, physics, and earth science.

How I view the present status

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

How I think it should be

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯

ERIC

9 1. I have never met/spoken with my child's science teacher.

5. I meet/speak with my child's science teacher at least once per grading period.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. I have never been involved in decisions about policy changes at my child's school.

5. I am heavily involved in decisions about policy changes at my child's school.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

11 1. I have no interest in being involved with decisions about policy changes at my child's school.

5. I would like to become/continue to be involved with decisions about policy changes at my child's school.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

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Statements for the School Board

(This section is optional.)

1 1. The relationship between the school board and the district administrators is generally poor.

5. The relationship between the school board and the district administrators is generally very good.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

2 1. I believe that a high school science education is only for students who are preparing for a career in science.

5. I believe that a high school science education is for all students regardless of their present choice of careers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

3 1. I believe that a high school science education is not essential.

5. I believe that a high school science education is at least as essential as an education in mathematics or English.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. Teachers should maintain responsibility and authority.

5. Teachers should share the responsibility for learning with students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

5 1. Teachers should encourage competition among students.

5. Teachers should encourage cooperation and shared responsibility among students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

6 1. Students should study biology, chemistry, physics, and earth science.

5. Students should take science classes that have all the sciences in them every year.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

7 1. Science is biology, chemistry, physics, and earth science.

5. Science that blurs the boundaries of the disciplines reflects the reality of the natural world.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

8 1. My district uses only multiple choice tests to measure the science achievement of students.

5. My district uses a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

9 1. Teachers should use only multiple choice tests to measure the science achievement of students.

5. Teachers should use a variety of assessments, including multiple choice questions, constructed response questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. Teachers should use the results of classroom assessments to assign students a grade.

5. Teachers should use the results of classroom assessments to improve their teaching and provide detailed feedback to students about their learning.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

11 1. Teachers should communicate student achievement to parents only via grades on report cards.

5. Teachers should communicate student achievement to parents using results from a variety of assessments, such as performance tasks and portfolios.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

12 1. Parents in my community would not support their students enrolling in classes that integrate concepts from biology, chemistry, physics, and earth science.

5. Parents in my community would support their students enrolling in classes that integrate concepts from biology, chemistry, physics, and earth science.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

13 1. My district uses very little of its Title II money for science professional development.

5. My district uses at least 40 percent of its money for science professional development.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

14 1. My district does not apply funds other than Title II funds to high school science professional development.

5. My district applies funds other than Title II funds to high school science professional development.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

15 1. The school board in my district is never involved in high school curricular changes.

5. The school board in my district is always involved in high school curricular changes.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

Statements for Teacher Educators

(This section is optional.)

1 1. I believe that a high school science education is only for students who are preparing for a career in science.

5. I believe that a high school science education is for all students regardless of their present choice of careers.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

2 1. I believe that a high school science education is not essential.

5. I believe that a high school science education is at least as essential as an education in mathematics or English.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

3 1. In my preservice teaching, I focus on students' acquisition of knowledge.

5. In my preservice teaching, I focus on students' understanding and use of scientific knowledge, ideas, and inquiry processes.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

4 1. In my preservice teaching, I present scientific knowledge through lecture, text, and demonstration.

5. In my preservice teaching, I guide students in active and extended scientific inquiry.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

5 1. In my preservice teaching, I ask students to recite acquired knowledge.

5. In my preservice teaching, I provide opportunities for students to engage in scientific discussion and debate.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

6 1. In my preservice teaching, I test students for factual information at the end of the unit or chapter.

5. In my preservice teaching, I continuously assess student understanding.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

7 1. Teachers should feel confident about my understanding of concepts in one of the following: biology, chemistry, physics, and earth science.

5. Teachers should feel confident about my understanding of concepts in all of the following: biology, chemistry, physics, and earth science.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

8 1. Teachers should organize their teaching around science content, much like the organization of a science textbook.

5. Teachers should organize their teaching around themes like systems, change, water, and energy.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

9 1. Teachers should maintain responsibility and authority.

5. Teachers should share the responsibility for learning with students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. Teachers should encourage competition among students.

5. Teachers should encourage cooperation and shared responsibility among students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

11 1. Teachers should make decisions about what to teach based on the content of a textbook.

5. Teachers should make decisions about what to teach based on content linked to Standards Benchmarks

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

12 1. My college's preservice program does not reflect the vision of national science education reform efforts.

5. My college's preservice program reflects the vision of national science education reform efforts.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

13 1. My college's preservice courses treat science disciplines as separate, unconnected topics.

5. My college's preservice courses help preservice teachers understand and teach science disciplines in a connected, integrated manner.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

14 1. My colleagues and I make all decisions about professional development inservice opportunities that we provide.

5. Teachers and other school district personnel are the source of ideas about professional development inservice opportunities that we provide.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

15 1. Teachers should focus on students' acquisition of knowledge.

5. Teachers should focus on students' understanding and use of scientific knowledge, ideas, and inquiry processes.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

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16 1. Teachers should present scientific knowledge through lecture, text, and demonstration.

5. Teachers should guide students in active and extended scientific inquiry.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

17 1. Teachers should ask students to recite acquired knowledge.

5. Teachers should provide opportunities for students to engage in scientific discussion and debate.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

18 1. Teachers should test students for factual information at the end of the unit or chapter.

5. Teachers should continuously assess student understanding.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

19 1. Teachers should maintain responsibility and authority.

5. Teachers should share the responsibility for learning with students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

20 1. Teachers should encourage competition among students.

5. Teachers should encourage cooperation and shared responsibility among students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

21 1. Students should study biology, chemistry, physics, and earth science in high school.

5. Students should take high school science classes that have all the sciences in them every year.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

22 1. Science is only biology, chemistry, physics, and earth science.

5. Science that blurs the boundaries of the disciplines reflects the reality of the natural world.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

23 1. Teachers should use only multiple choice tests to measure the science

5. Teachers should use a variety of assessments, including multiple choice questions, constructed response (essay) questions, hands-on performance tasks, and portfolios to measure the science achievement of students.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

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24 1. Teachers should use the results of classroom assessments to assign students a grade.

5. Teachers should use the results of classroom assessments to improve their teaching and provide detailed feedback to students about their learning.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

25 1. Teachers should communicate student achievement to parents only via grades on report cards.

5. Teachers should communicate student achievement to parents using results from a variety of assessments, such as performance tasks and portfolios.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

26 1. Teachers should tell students their grades.

5. Teachers should provide students with opportunities to evaluate their own learning.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

27 1. Science professional development in which my college is involved targets only teachers.

5. Science professional development in which my college is involved targets both teachers and administrators.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

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28 1. My college provides professional development for high school science teachers primarily in the form of one- to two-hour discrete workshops or by sending teachers to conferences or conventions.

5. My college has a sustained, ongoing system of professional development for high school science teachers.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

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Statements for Business and Industry

(This section is optional.)

1 1. I don't think that a strong science education is crucial to preparing students for college.

5. I think that a strong science education is crucial to preparing students for college.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

2 1. I don't think that a strong science education is crucial to preparing students for the workplace.

5. I think that a strong science education is crucial to preparing students for the workplace.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

3 1. Science was not a very strong subject for me in high school.

5. Science was a strong subject for me in high school.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

4 1. I believe that high school science education is only for students who are preparing for a career in science.

5. I believe that high school science education is for all students regardless of their present choice of careers.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

5 1. I believe that a high school science education is not essential.

5. I believe that a high school science education is at least as essential as an education in mathematics or English.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

6 1. Science is biology, chemistry, physics, and earth science.

5. Science that blurs the boundaries of the disciplines reflects the reality of the natural world.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

7 1. My business/industry is never involved in science curricular changes in my community.

5. My business/industry is heavily involved in science curricular changes in my community.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

8 1. My business/industry has no scientific or technical orientation.

5. My business/industry has a strong scientific or technical orientation.

How I view the present status

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

How I think it should be

1 ○ 2 ○ 3 ○ 4 ○ 5 ○

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9 1. My business/industry never contributes or shares resources with the school district in my community.

5. My business/industry contributes or shares resources generously with the school district in my community.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

10 1. Science is not important to the economic improvement of our country.

5. Science is important to the economic improvement of our country.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

11 1. Science is not important to the skills and abilities of our future workforce.

5. Science is important to the skills and abilities of our future workforce.

How I view the present status

1 2 3 4 5

How I think it should be

1 2 3 4 5

APPENDIX D

Next Step Questions: Questions to Consider before Making a Decision

After the district leadership team has completed the needs assessment and has analyzed the results, the team is ready to revisit some fundamental questions and consider some new ones. The following questions represent a place to begin.

1. What are your specific goals for students with respect to integrated science? What do you want them to learn?

2. How do your goals for students with respect to integrated science align with the state, district, and national goals?

3. What evidence does the district have that integrated science programs are successful? Is this enough evidence upon which to base a change?

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4. Do you think that integrated science will meet the needs of many students in your high school?

5. Will integrated science be offered to all students?

6. How does integrated science at the high school level articulate with the greater science program at the district level?

7. What background knowledge and skills will the students have when they enter an integrated science class?

8. What will the teachers' expectations of their students be?

9. How will integrated science prepare the students for the future?

10. Based on your goals for students with respect to integrated science, how much instruction time do you want to dedicate to it?

11. How will you assess student learning?

12. How will your district support the necessary professional development of teachers, especially with respect to their content knowledge across the discipline boundaries?

13. How will the district ensure that teachers have other resources that they need to implement integrated science?

14. How can you use integrated science to attend to often-overlooked standards (for example, history and the nature of science)?

15. What will you integrate (for example, science disciplines, concepts, threads such as math and technology)?

16. What are the incentives for teachers?

17. What are the hurdles for teachers?

18. What will the professional development opportunities look like?

19. How will the district respond to questions about the academic soundness of the integrated science approach?

20. How might an integrated science program meet the academic standards that various constituencies expect (for example, administrators, parents, school boards, businesses, and college admissions officials)?

APPENDIX E

The Integrated Science Program at Your School: Guidelines for Writers

[The writers of the scenarios in Chapter 4 followed these guidelines.]

As you develop and write your integrated science (IS) scenario, please organize it into the following main categories. As you write each section, please incorporate answers to each set of questions. Do not list the question and then write your answer; rather, write your scenario in a coherent manner so that you provide answers to these questions. The number of words suggested for each section is just a guideline; write what you need to so that you provide the important information that reflects your experience.

DESCRIPTION OF YOUR SCHOOL (150–200 words)

1. What is the student population of your school?
2. How would you describe the character of your school district?
3. What is your science program like?
   a. State or district standards
   b. State or district assessments
4. What are the graduation requirements in science?

Description of the IS Program at Your School

(200–250 words)

1. At what grade level(s) is IS taught?
2. How many years is your IS program? Which years?
3. Who takes this course? What percentage of students? Which students?
4. Provide a detailed overview of the program content:
   a. Vehicle for integration
   b. Scope and sequence with particular concepts outlined

Background of the IS Program—Including Hurdles

(400–500 words)

1. What was the impetus for change?
2. What background work took place before changes began?
3. Which stakeholders were involved in the decision-making process?
   a. Was there a consensus?
   b. How were differences in opinions addressed?
4. What was the time line for change?
5. What was the educational climate?
6. What were the implications for professional development? How were they addressed?
7. What were the financial implications of the changes? How were they addressed?

Concerns of the Stakeholders (1,800–2,000 words)

Teachers

1. Who is teaching IS?
2. How were those teachers selected?
3. What type of professional development opportunities existed for them at the beginning and now?
4. What is the range of attitudes that teachers teaching IS have with respect to their IS classrooms?
5. Have you seen a change in attitudes since the initial implementation of IS programs?

Students

1. Who is taking IS?
2. What choices in science courses do they have?
3. What do students say about their experiences in the IS classroom? What are their attitudes?
4. What do their test scores show?

PARENTS

1. Have parents been receptive to the changes?
2. How have their attitudes and concerns been addressed?
3. How have their attitudes changed across time?

ADMINISTRATION

1. Have principals, science supervisors, and curriculum specialists been supportive?
2. Have they supported the necessary changes in the structure of the school day—providing team-teaching and team-planning time?
3. Have they provided teachers with professional development opportunities to help them implement IS?
4. Are they supportive of the leave time that teachers need?

SCHOOL BOARD

1. What was the school board's role in implementing these changes?
2. How much support have members provided schools and teachers?

COLLEGES

1. Did your school district determine whether colleges and universities will accept IS for college admissions?
2. How successful was that endeavor?
3. What are you finding as students who have taken IS apply to colleges?

CURRICULUM MATERIALS FOR THE IS PROGRAM (500 words)

1. How did you decide what curriculum to use?
2. Are you using commercial textbooks? If so, which ones?
3. Are you using district-developed curriculum? If so, to what extent? Who develops it?
4. Are teachers responsible for finding their own materials?
5. How effective are your materials?
6. What changes have you made in your curriculum since you began?
7. If your area is producing its own curriculum, is there enough time, resources, expertise, and general support to do so?

Assessment (250–300 words)

1. How do you assess your students?
2. How is assessment in IS different from assessment in discipline-specific programs?
3. Do you assess concepts that cross discipline boundaries?
4. How do students perform on such assessments?
5. How do students perform on standardized tests?
6. How do students perform on state exit exams?

Plans for the Future (100 words)

1. Do you have any plans to expand the IS program at your school or in your district?

Other Characteristics of Your IS Program or Experience (200–300 words)

1. Are there other aspects of the IS experience at your school that you feel are important?

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Appendix F

Frequently Asked Questions about Integrated Science at the High School Level

Below, we provide brief answers to some of the frequently asked questions about integrated science. For more in-depth answers, we refer you to sections of this guide.

1. What exactly is integrated science (IS)? Chapter 1

   The concept of integrated science means different things to different people. In fundamental terms, it represents a course of study in the sciences that draws on content and concepts from all of the major disciplines of science—earth science (including space science), life science (biology), and physical science (chemistry and physics). In some models of integrated science, the goal is to provide activities and studies that integrate all of the disciplines all of the time. In other models, the goal is to teach concepts from all of the disciplines, but not necessarily to integrate all disciplines in every lesson or every unit. For

a complete discussion of a range of models and vehicles for integrating the content, see Chapter 1.

Introduction
Chapter 1

2. Why have schools started offering integrated science courses?

Schools have started offering integrated science courses for a number of reasons including the following: the need to meet state and national standards in all of the disciplines of science; the need to engage a greater diversity of students in science; the need to prepare students for high school exit exams that cover the sciences; and the need to provide a coherent alternative to the traditional sequence of biology, chemistry, and physics. For a complete discussion, see the Introduction and Chapter 1.

Appendix H
Chapter 4

3. How many states currently offer integrated science programs at the high school level and at what grade or grades?

Currently, thirty-one states report offering some integrated science at the high school level. A few states, such as West Virginia, are mandating integrated science for ninth and tenth graders. In some states, such as Florida, school districts are offering two- or three-year sequences in integrated science as a coherent, alternative course of study but offer the traditional sequence as well. Many states have only a few school districts offering integrated science. Most states that offer integrated science, offer it to ninth and tenth graders, and many states are expanding their offerings to eleventh and twelfth graders as well. For a state-by-state status report, see Appendix H. For a detailed description of three actual scenarios in three school districts, see Chapter 4.

Chapter 4

4. Who takes integrated science?

Across the country, students of all academic abilities and inclinations are taking integrated science. The idea that integrated science is only for students who are not planning to take any more science or are not planning to go to college is an idea of the past. Currently, students of all abilities and inclinations are enrolled in integrated science classes. In general, students find that integrated science engages them in science in ways that other science classes do not. For a description of students who take integrated science, see the three scenarios in Chapter 4.

5. What do the students learn? How effective are these courses in enhancing students' understanding of concepts in science? Chapter 4

The impact that integrated science has on student learning is, of course, a central concern. In some states, such as California and Florida, where integrated science has been in the schools for a while, we are beginning to see some good data, but it is also difficult to get true comparison studies. In general, if the quality of the program and the quality of the teaching are both high, it seems that students are learning at least as much as students in traditional classes. In Brevard County, Florida, where they offer both integrated science and the traditional sequence, they are finding that the overall science scores are going up. We do not anticipate that students will necessarily learn more in integrated science than they do in other science courses, but that more students may have an opportunity to learn a coherent set of connected concepts in science. We encourage all schools and districts to carefully collect information about student learning in integrated science, to allow the results to inform instruction, and we ask that you share your results with the rest of us. For some results with respect to student learning, see the three scenarios in Chapter 4.

6. Who teaches integrated science? What about certification? Chapter 4

Across the country, the reality is that teachers from all of the sciences are teaching integrated science. Some teachers are teaching integrated science because they want to, and some teachers are teaching integrated science because that is their assignment. Some states certify teachers by specific discipline, and some certify teachers in general science only. California and Utah, for example, are now offering a type of integrated (or coordinated or unified) teaching credential. For a description of the teachers of integrated science, see the three scenarios in Chapter 4.

7. What about admissions to college? Chapter 4

The issue of college entrance has been a big concern all along, but state by state and college by college, it looks as though this problem eventually will be solved for the majority of colleges. There are three main lessons that we have learned from school districts that already have been through the process: (1) be cer-

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tain that there is a lab component in the integrated science course that you develop, (2) write the course description carefully and thoroughly to include all disciplines and the lab component, and (3) communicate with colleges and universities early in the process and ask them for letters approving your courses. Brevard County, Florida, has been very successful in having colleges across the country accept integrated science credits (see the Florida Scenario in Chapter 4).

Appendix G

8. What curriculum materials are available for teaching integrated science? What materials are under development?

Some relatively new curriculum materials are available for teaching integrated science at the high school level, and there are more currently under development. In addition, we have found that many schools and districts develop their own materials. See Appendix G for a description of the current curriculum materials.

Chapter 2
Chapter 3
Chapter 4

9. What is the best way to implement such a program?

The most successful integrated science programs are those in schools and districts that have taken the time to plan carefully and address the concerns of all stakeholders along the way. These successful programs also implemented the change slowly across several years. For a detailed description of planning for change and implementing an integrated science program, see Chapters 2 and 3 as well as the scenarios in Chapter 4. The Florida Scenario outlines a detailed and incremental implementation plan.

Chapter 3
Chapter 4

10. What are the challenges of implementing an integrated science program in high schools?

The challenges will vary from school to school and district to district. Many of the challenges are predictable and to be expected, such as resistance from some teachers; the professional development needs of teachers; the small supply of curriculum materials; the questions from students, parents, and school board members; the problems of structuring the school day to accommodate the needs of teachers; and the articulation with science course work across grade levels. For a detailed description of planning for implementation, see Chapter 3. For details on how

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integrated science programs were implemented in three school districts around the country, see Chapter 4.

11. How can schools best help teachers prepare to teach integrated science?

Chapter 2
Chapter 3
Chapter 4
Appendix A

It is no surprise that the most successful programs in integrated science are in school districts where the teachers are supported both philosophically and practically as they implement the new program. Schools can help by planning carefully, including teachers in all decision-making processes, providing for and funding the initial and ongoing professional development needs of teachers, and providing some flexibility in structuring the school day. For details about how schools might best do this, see Chapters 2 and 3. For details on what three different schools and districts did to support teachers, see the three scenarios in Chapter 4. The Florida Scenario outlines the most support for teachers. For details of the Concerns-Based Adoption Model and how it relates to implementing integrated science, see Appendix A.

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APPENDIX G

List of Curriculum Materials for Integrated Science

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List of Recent, NSF-Funded Curriculum Materials for Integrated Science at the High School Level

Name of Program	Developer and Principal Investigator	Publisher	When Available	Grade Level	Format
The Changing Global Environment (one-year ecology-based program)	Brian Drayton, TERC, Cambridge, MA	Kendall/ Hunt Publishing Company, Dubuque, IA	currently available	11 or 12	three modules
Prime Science (builds on the Salter's Science Project)	Penny Moore, University of California–Berkeley	Kendall/ Hunt Publishing Company, Dubuque, IA	currently available	9–10 (6–8 also)	textbooks
Global Laboratory (one-year, Web-based, environ-mental studies program)	Boris Berenfeld, TERC, Cambridge, MA	Kendall/ Hunt Publishing Company, Dubuque, IA	spring 2000	high school	five units, student research guide
Earth Sciences in the Community (EarthCom) (an earth-science-based program)	Michael Smith, AGI, Alexandria, VA	It's About Time Publishing, Armonk, NY	August 2000	9–12	modules, teacher resources
Voyages through Time (one-year, technology-based curriculum focusing on evolu-tion)	Jill Tarter, SETI Institute, Los Altos, CA		May 2002	high school	six modules
Science and Sustainability (one-year program, part of the SEPUP series)	Herbert Thier, Lawrence Hall of Science, University of California–Berkeley	Lab-Aids, Ronkonkoma, NY	currently available	10–12	four modules

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APPENDIX H

Survey Results

During 1999, BSCS surveyed the offices of state science supervisors to determine the interest in and current status of integrated science programs at the high school level across the country. We coordinated these results with information from the Chief Council of State School Officers (CCSSO, 1998) and have included statements from teachers around the country.

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Survey Responses from the Offices of State Science Supervisors

State	How many years of science required for graduation?	What is your level of interest in integrated science at high school?	Do high schools in your state offer integrated science?	If so, at what grade level(s) is it offered?
Alabama	4	medium	no	–
Alaska	2	medium	yes	9
Arizona	2	high	yes	9
Arkansas	3	medium	yes	9
California	2	high	yes	9–12
Colorado	local board determines	medium	yes	9–10
Connecticut	2	medium	yes	9–10
Delaware	2	no response	–	–
District of Columbia	3	high	yes	9
Florida	3	high	yes	9–12
Georgia	3	high	yes	9–10
Hawaii	3	no response	–	–
Idaho	2	medium	yes	9–10

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State	Are the courses in integrated science in your state effective?	What are your major concerns about integrated science at the high school level?	Are there plans to expand the integrated science programs?
Alabama	—	college entrance requirements	—
Alaska	—	professional development needs	dont' know
Arizona	too soon to tell	professional development needs, teacher certification	yes
Arkansas	too soon to tell	teacher resistance	don't know
California	yes	professional development needs, teacher resistance	yes
Colorado	too soon to tell	college entrance, lack of curriculum materials	don't know
Connecticut	yes	still have a need for discipline-specific content	maybe
Delaware	no response	—	—
District of Columbia	don't know	lack of curriculum materials	maybe
Florida	yes	professional development needs, some teacher resistance	yes
Georgia	don't know	teacher resistance, high school competency exam	—
Hawaii	no response	—	—
Idaho	don't know	lack of curriculum materials	—

State	How many years of science required for graduation?	What is your level of interest in integrated science at high school?	Do high schools in your state offer integrated science?	If so, at what grade level(s) is it offered?
Illinois	1	low	yes	9
Indiana	2	medium	yes	9–10
Iowa	local board determines	high	yes	9–10
Kansas	2	medium	no	–
Kentucky	3	high	no	–
Louisiana	3	high	no	–
Maine	2	high	no	–
Maryland	3	medium	yes	9–10
Massachusetts	local board determines	high	yes	10–11
Michigan	local board determines	high	yes	9–12
Minnesota	standards based	high	yes	9–10
Mississippi	3	medium	no	–
Missouri	2	low	no	–
Montana	2	medium	no	–

State	Are the courses in integrated science in your state effective?	What are your major concerns about integrated science at the high school level?	Are there plans to expand the integrated science programs?
Illinois	don't know	professional development needs	–
Indiana	too soon to tell	assessments for integrated science	maybe
Iowa	too soon to tell	teacher resistance, college entrance requirements	yes
Kansas	–	college entrance requirements	–
Kentucky	–	lack of curriculum materials	–
Louisiana	–	lack of curriculum materials	–
Maine	–	professional development needs	–
Maryland	yes	assessment in integrated science	–
Massachusetts	don't know	tenth-grade state exam, teacher resistance	maybe
Michigan	don't know	professional development needs, state exam in science	–
Minnesota	yes	lack of curriculum materials, state competency tests	maybe
Mississippi	–	professional development needs	–
Missouri	–	teacher resistance	–
Montana	–	teacher resistance, professional development needs	–

State	How many years of science required for graduation?	What is your level of interest in integrated science at high school?	Do high schools in your state offer integrated science?	If so, at what grade level(s) is it offered?
Nebraska	local board determines	high	no	–
Nevada	2	high	yes	9–10
New Hampshire	2	medium	yes	9–10
New Jersey	2	high	yes	9–11
New Mexico	2	medium	yes	9
New York	2	medium	no	–
North Carolina	3	no response	–	–
North Dakota	2	medium	yes	9
Ohio	1	low	no	–
Oklahoma	2	no response	–	–
Oregon	2	high	yes	9–10
Pennsylvania	under revision	high	yes	9–10
Rhode Island	2	medium	no	–
South Carolina	2	medium	no	–
South Dakota	2	high	yes	9–11

State	Are the courses in integrated science in your state effective?	What are your major concerns about integrated science at the high school level?	Are there plans to expand the integrated science programs?
Nebraska	–	teacher resistance	–
Nevada	yes	professional development needs, high school proficiency exam	maybe
New Hampshire	–	lack of curriculum materials	maybe
New Jersey	don't know	college entrance requirements, high school proficiency test	yes
New Mexico	don't know	college entrance requirements	maybe
New York	–	Regent's exam, lack of curriculum materials	–
North Carolina	no response	–	–
North Dakota	don't know	lack of curriculum materials	maybe
Ohio	–	professional development needs	–
Oklahoma	no response	–	–
Oregon	yes	professional development needs, teacher certification	maybe
Pennsylvania	yes	teacher resistance, assessment in integrated science	yes
Rhode Island	–	teacher certification, teacher resistance	–
South Carolina	–	teacher resistance	–
South Dakota	don't know	lack of curriculum materials	–

State	How many years of science required for graduation?	What is your level of interest in integrated science at high school?	Do high schools in your state offer integrated science?	If so, at what grade level(s) is it offered?
Tennessee	3	medium	no	—
Texas	2	low	no	—
Utah	2	high	yes	9
Vermont	5 (math and science combined)	medium	no	—
Virginia	3	high	yes	9–10
Washington	2	high	yes	9–12
West Virginia	3	high	yes	9–10
Wisconsin	2	medium	yes	9–10
Wyoming	3	high	yes	9

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State	Are the courses in integrated science in your state effective?	What are your major concerns about integrated science at the high school level?	Are there plans to expand the integrated science programs?
Tennessee	–	teacher resistance	–
Texas	–	state exit exams, college entrance requirements	–
Utah	yes	teacher resistance	–
Vermont	–	professional development needs	–
Virginia	don't know	teacher certification, state end-of-course exams	–
Washington	yes	lack of curriculum materials	yes
West Virginia	too soon to tell	lack of curriculum materials	yes
Wisconsin	don't know	assessments in integrated science, lack of curriculum materials	maybe
Wyoming	too soon to tell	professional development needs	–

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A Sampling of Comments from Teachers and Administrators Around the Country

Comments on the rationale for teaching integrated science:

"We are a rural district of 800 students and one high school. Teaching it (integrated science) for six years at high school level (grades 9–12). I believe it is the *best* reasonable way to meet Washington State standards by grade ten."

Teacher, Washington

"As an effective way of meeting state standards and keeping interest high. Some areas seem to naturally lend themselves more to integrated science, such as environmental science and biology/chemistry."

Science Department Chair, Pennsylvania

"It is a definite way to assure all students can meet the national standards."

Teacher, Arizona

"Don't like to see kids going to college with their last physics in the eighth grade."

Teacher, Missouri

"Remember that high school students aren't *all* college prep ... but they *are* consumer and citizen prep."

Teacher, Minnesota

"With the new standardized testing in our state, we need to look at programs that will work for us. I think an integrated science program will."

Teacher, Massachusetts

Comments about teaching integrated science:

"We are going to an integrated program completely by 2000–2001."

Teacher, Arizona

"We have tried to develop such a program for the last two years."

Teacher, Illinois

"I feel all of our science programs will move toward a 9–10 integrated science sequence due to state testing."

Teacher, Arizona

"Our district is implementing a spiral approach K–8 and planning integrated science for 9–10 or 9–12."

Science Department Chair, Wisconsin

"We need a coherent, curriculum program that is conceptually appropriate for the high school level."

Teacher, Wisconsin

"They meet with a lot of teacher resistance at high school level."

District Science Supervisor, Florida

"At our school, we offer Integrated/Coordinated Science 1 and 2, and all students taking science take these courses."

Teacher, California

"Teaching integrated science has definitely increased the interest in science at our school and has increased the enrollment in science classes beyond the two-year requirement."

Science Department Chair, California

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